SH&E International Air Transport Consultancy

SCAG REGIONAL AIRPORT DEMAND MODEL

LITERATURE REVIEW

Prepared for:

SOUTHERN CALIFORNIA ASSOCIATION of GOVERNMENTS

Prepared by:

Dr. Geoffrey D. Gosling

With:

Cambridge Systematics, Inc.
SH&E, Inc.

June 2003

Project #5437

ACKNOWLEDGEMENTS

This report was prepared as part of a contract with the Southern California Association of Governments for the development of a Regional Airport Demand Model. The author wishes to acknowledge the contribution of other members of the project team, including David Hollander from SH&E, and Kevin Tierney and Yasasvi Popuri from Cambridge Systematics, Inc. Valuable assistance in identifying relevant literature pertaining to previous work for the Southern California region was received from staff at the Southern California Association of Governments, as well as Paula McHargue, Susan Collette and Patrick Tomcheck from the Los Angeles World Airports. Salah Mumayiz of BAE Automated Systems provided helpful information on airport demand modeling performed as part of studies for the proposed Third Chicago Airport.

Several sections of the report have been adapted and expanded from material originally prepared by the author and others as part of research undertaken at the Institute of Transportation Studies at the University of California, Berkeley, with funding from the California Department of Transportation and documented in Working Paper UCB-ITS-WP-94-5, Airport Choice and Ground Access Mode Choice Models: A Review and Analysis of Selected Literature (Mark E. Lunsford and Geoffrey D. Gosling, June 1994).

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

TABLE OF CONTENTS

Acknowledgements i

Executive Summary ii

1. Introduction 1

2. Airport Demand Allocation Models 3

3. Airport Ground Access Mode Choice Models 14

4. Air Passenger Trip Generation Models 19

5. Air Service Forecasting Models 22

6. Local Planning Agency Airport Ground Access Modeling 24

7. Implications for the SCAG Regional Airport Demand Model 31

References 33

APPENDICES – Annotated Bibliography

A. Airport Demand Allocation Models 39

B. Airport Ground Access Mode Choice Models 74

C. Air Passenger Trip Generation Models 98

D. Air Service Forecasting Models 102

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

EXECUTIVE SUMMARY

This report presents a review and analysis of the literature on airport demand allocation models and three related topics: airport ground access mode choice models, air passenger trip generation models, and air service forecasting models. The report addresses what issues and ideas are important to consider in developing these models and makes recommendations for further development of such models. Issues of airport choice and airport ground access mode choice are central to airport system planning in multi-airport regions and to ground access planning at all airports. Not surprisingly, therefore, such models have received a fair amount of attention in the literature. There appears to be a growing agreement on the general form that these models should take, although the details of the functional form vary widely from study to study, making comparison of the resulting model coefficients difficult.

The review identified and summarized 28 reports or papers describing the development or application of airport choice models and 12 reports or papers documenting airport ground access models. These models used a wide range of functional forms and explanatory variables. Although it does not yet appear that a consensus has emerged on the detailed functional form or variables to be included, there does appear to be a growing acceptance that the nested logit model presents the most effective structure for analyzing airport choice and ground access mode choice.

Experience has shown that travelers should be classified into categories by both trip purpose and resident or non-resident status and separate model parameters estimated for each category in order to obtain the best explanatory power. However, the review concluded that other less traditional classifications, such as by length of haul, should also be studied. For airport choice models, variables accounting for air fare, flight frequency, and overall ground access service have been found to be effective. For ground access mode choice models, variables accounting for travel time, travel cost, and income have been shown to be important. Other variables, such as the amount of luggage and the gender of the traveler have been shown to influence the use of public transportation modes.

However, partly as a result of differences in functional form and partly as a result of differences in the datasets used to calibrate the models, there is very little consistency in the parameter values estimated across the different models. Thus it is unclear whether there is an underlying behavioral pattern that is consistent across different communities and situations. This makes the transferability of any of the models extremely questionable.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

For both types of model, there is a need to experiment with new variables in the utility functions and to attempt to resolve the inconsistent results presented in the literature. Additional variables would be especially useful if they enable the models to better address such policy aspects as travel time reliability, walking distance involved in connections between public transportation modes, or the ability to check baggage at off-airport locations.

In contrast to airport choice and airport ground access mode choice, very little work appears to have been done to model air passenger trip generation at the zonal level, or to forecast how air service can be expected to evolve in a multiple airport region. The review identified four reports or papers addressing airport trip generation, nine reports or papers addressing various relevant aspects of air service forecasting and two papers that describe models to explicitly predict levels of air service. Since both issues are critical to the process of modeling the future allocation of air passenger demand in a multiple airport region, these are aspects that will require careful attention in the development of the regional airport demand model.

Finally, the review summarizes the current state of the art of airport ground access modeling as addressed in local planning agency surface transportation modeling efforts elsewhere in the United States and in selected studies in other countries.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

1 INTRODUCTION

Issues of airport choice and airport ground access mode choice are central to airport system planning in multi-airport regions and to ground access planning at all airports. The ability to model how air passengers choose which airport to use in a multi-airport region, and which ground access mode to use for the journey to or from the airport, is an essential requirement in evaluating the consequences of any proposed action that could affect such choices. These actions can range from something as significant as constructing a new airport to such routine decisions as changing airport parking rates.

Analytical models allow an aviation planner to understand the airport choice process in a particular region, by showing which variables are important and how important they are to different types of travelers. They allow the planner to evaluate how changes in airport supply variables, ground access supply variables, and socioeconomic variables will affect the distribution of flights between airports and the use of different modes of access to these airports.

Not surprisingly, therefore, such models have received a fair amount of attention in the literature. Unfortunately, there appears to be very little agreement on the precise form that these models should take, and a lack of familiarity among airport planners with those models that do exist.

This report presents a review and analysis of selected literature related to airport demand allocation models. This report discusses the issues involved in airport choice and ground access mode choice in the context of modeling how air passenger demand evolves in a multi-airport urban region. In addition to the airport choice behavior of air passengers and their airport ground access mode choice decisions, the review also examines two other aspects that are critical to the process of modeling the future allocation of air passenger demand in a multiple airport region: modeling air passenger trip generation at the zonal level, and forecasting how air service can be expected to evolve in such a region. The former is necessary to be able to project where future air passenger trips will begin and end in the region, while the latter forms an essential input to the demand allocation process.

The purpose of the review is to determine what issues and ideas are important to consider in developing these types of models and to make recommendations for further development of such models. Recommendations are made for model form, important variables, and calibration technique, based on the experience of previous choice modeling efforts, as well as suggestions for improvement that have been identified in the course of the literature review.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

The report provides an overview of the important issues involved in airport choice and ground access mode choice modeling, and is based on identifying those methods that worked well in past modeling efforts, those that were less successful, and suggestions for new ideas that should be tried. Many of the ideas presented in this report were derived from suggestions of the authors in the literature reviewed. Many were quite open about the problems and limitations of their models, and they often gave suggestions on how they could be improved.

The body of this report contains a summary of the literature and a discussion of the implications for the development of airport demand models for Southern California, while four appendices contain an annotated bibliography that provides detailed descriptions of selected studies and individual models. Chapter 2 provides an overview of airport demand allocation models. Chapter 3 addresses airport ground access mode choice models. Chapter 4 examines air passenger trip generation models, while Chapter 5 discusses air service forecasting models. Chapter 6 was contributed by Cambridge Systematics and summarizes the state of the art of local planning agency airport ground access modeling. Finally, Chapter 7 presents some conclusions that can be drawn from the literature review and discusses the implications for modeling airport demand in the Southern California region. Appendices A and B provide a detailed description of selected airport choice and airport ground access mode choice models. Appendix C provides comparable information for air passenger trip generation models, while Appendix D provides an annotated bibliography on studies related to the development of air service forecasting models.

2 AIRPORT DEMAND ALLOCATION MODELS

A basic assumption in the models of airport choice that were reviewed is that airports do not have unique catchment areas. Travelers do not simply use the closest airport but choose between all the airports serving a region (Ashford and Benchemam, 1987). It seems logical to assume that a region with many airports (such the Southern California metropolitan area) will have more competition between airports because there will be more choices for the air traveler. It is, therefore, more important to understand the factors that determine airport choice in these regions.

IMPORTANT VARIABLES

Ashford and Benchemam (1987) considered air fare, flight frequency, and access travel time to be the most important variables. These were actually the only three variables that they used in their model. They chose these three variables because they were the most frequently cited reasons for choosing an airport in a 1978 survey by the United Kingdom Civil Aviation Authority.

Harvey (1988) considered flight frequency and some measure of ground access quality as the most important variables in airport choice. A 1980 survey of air travelers performed by the San Francisco Bay Area Metropolitan Transportation Commission showed that an airport's proximity to travelers' home and work and its ease of access/egress were the dominant factors involved in airport choice. The next most important factor was flight availability and convenience. Harvey (1987) also identified air fare as a potentially important variable but did not include it in his model because the Bay Area survey did not include the fare class of each traveler.

More recent studies have generally included some measure of airport accessibility and flight frequency, although the different studies defined these measures in different ways. The extent to which air fare differences are included in the model varied between the studies.

The Regional Airport Demand Allocation Model (RADAM) developed for the Southern California Association of Governments (SCAG, 2002) has reportedly the largest number of variables of any of the models reviewed, although details of how these variables are included in the model are somewhat vague. Since this model is the only one reviewed that has been developed specifically for Southern California, and is currently used by SCAG to support its regional aviation system planning, this is discussed in more detail later in this chapter.

AIR FARE

Air fare is a very important variable if there is a difference in fares between airports, particularly for non-business travelers. For example, Ashford and Benchemam (1987) found that airfare was more important than flight frequency or travel time. However, a significant problem with including air fare in models is that it is not often included in air passenger surveys. Harvey (1987) identified the air fare as the only omitted variable of possible major consequence in his model.

Among the more recent studies, Furuichi and Koppelman (1994) and Pels et al. (1998) included air fare terms, while Mandel (1999) included trip cost rather than the air fare itself.

FLIGHT FREQUENCY

The frequency of flights to the traveler's destination is an important variable that was used in some form by both Ashford and Benchemam and Harvey in their airport choice models.

Harvey (1988) defined two variables that capture the effect of frequency on airport choice: relative frequency and daily frequency. Relative frequency was defined as the number of flights to the air party's destination from a given airport divided by the sum of flights to the same destination from all the airports in the study region. Connecting and commuter flights were omitted. Daily frequency was defined as the number of flights per day from a given airport to the air party's destination. He used the following parabolic form of the daily flight frequency variable to account for the decreasing marginal utility of flight frequency:

$$f(DF) = 18 * DF - DF2$$

Connecting flights were omitted, as were any flights beyond the ninth daily flight. This cutoff of nine flights was determined empirically.

Harvey believed that the decreasing marginal utility of flight frequency was caused by some negative attribute that is strongly correlated to high flight frequency, such as terminal congestion. However, it seems more likely that it simply reflects the diminishing effect on headway of adding flights and that a better way to specify the model would be to use the inverse of flight frequency (headway) in the utility function, rather than the flight frequency itself. The parabolic relation that Harvey used can be thought of as an approximation to the inverse.

Ashford and Benchemam (1987) defined only one variable related to flight frequency: the number of flights per day from an airport to the air party's destination.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Representation of flight frequency in more recent studies varied from a direct measure of the number of weekly flights, through the use of the logarithm of the flight frequency (Hansen, 1995), to the inverse of the weekly frequency with a calibrated term to reflect the ability of travelers to adjust their travel schedules to conform to available flight departures in markets with less frequent air service (Halcrow Group et al., 2002). It is clear that there should be a diminishing return to flight frequency in terms of passenger convenience, so an inverse or quasi-inverse (such as logarithmic) relationship is intuitively preferable to a direct measure of the frequency.

OVERALL GROUND ACCESS QUALITY

Airport choice and ground access characteristics are not independent. For this reason, Ashford and Benchemam (1987) used ground access travel time as a variable in their model. They found it to be the most important variable for business travelers. However, the problem with travel time is that it does not provide a comprehensive representation of ground access quality at an airport. Travel time should be replaced with some better representation of ground access that includes such factors as the perceived variance in access time, the number of possible modes of access, travel costs, and parking costs.

Harvey included ground access quality in his airport choice model with a variable that represented the expected utility from the ground access mode choice model. He considered this an improvement over models that only consider highway access time, since it is a more comprehensive measure of the quality of ground access at an airport. This approach is recommended as a theoretically sound measure of the overall ground access quality experienced by a traveler.

Mandel (1999) followed this approach, using a nested structure with an explicit modeling of airport ground access mode choice to define an access disutility in the higher level airport choice process. Other studies have simply used ground access travel time, typically highway travel time (Windle & Dresner, 1995; Pels et al., 1998), or a combination of travel time and cost (Furuichi & Koppelman, 1994; Bondzio, 1996). A model for the South East and East of England Regional Air Service (SERAS) Study, described in more detail below, used a generalized access cost that combined cost and travel time for three different modes, private automobile, coach and rail (Halcrow Group et al., 2002), with a cost penalty for the number of interchanges involved in coach and rail modes.

SECONDARY VARIABLES

Even though the findings of the two major airport choice studies are consistent, other variables should be analyzed because this type of modeling is still fairly new and many scenarios have not yet been investigated. Harvey (1988) suggested that the following variables should be considered for improving airport choice models: frequency of connecting flights, air trip duration, income, air party size, number of pieces of luggage, and air travel experience. Bondzio (1996) used a nested model structure that included air passenger income and amount of luggage in the ground access mode choice component. Mandel (1999) also used a nested structure that included distance, travel time and the number of intermediate stops in the airport choice component and a number of other variables in the ground access mode choice component.

Some of these additional variables appear to be more appropriate for inclusion in the utility functions of a ground access mode choice model than directly in an airport choice model. The use of a nested structure, combining airport choice and ground access mode choice, allows these variables to have an indirect effect on airport choice.

The airport choice models reviewed appear to suggest that a few important variables dominate airport choice. Once these variables are identified, adding other variables is unlikely to significantly improve the performance of the models and could make the calibration of such models more difficult. There is a need to identify which variables dominate the choice process for each separate classification of traveler and which variables are secondary.

AIRPORT DEMAND ALLOCATION

Although the primary motivation for developing airport choice models is to understand (and predict) how the demand for air travel in a region distributes itself among the available airports, only some of the models examined explicitly addressed the issue of how the choice process itself influences the air service that is offered at each airport. Other models simply attempted to explain the observed distribution of air passengers among multiple airports (when the air service pattern at each airport is of course known). To apply such models to forecast future distribution of air passengers, one must make assumptions about future levels of air service, model the resulting distribution of air passengers, and then determine if this distribution seems reasonable given the assumed pattern of air service. If the distribution of demand does not seem consistent with the air service assumptions, the air service assumptions would need to be revised and the model re-run until a satisfactory solution is obtained.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

The first model to explicitly address how the demand allocation affects the air service that can be offered at the various airports serving a region was the Multiple Airport Demand Allocation Model (MADAM) (Campbell, 1977). This model assigns demand to regional airports then adjusts the flight frequencies in each market from each airport to reflect the traffic volume. This in turn affects the demand allocation process, and the model iterates until an equilibrium is reached.

In two different studies applying MADAM, the statement is made that it can only be applied to domestic scheduled air carrier service. Apparently this limitation arises from the source of air travel demand forecasts. In one study the demand for air passenger travel to cities external to the Washington D.C. area (the study area) was derived from the Civil Aeronautics Board Origin and Destination Survey. Since the survey included only scheduled air carrier service between domestic city pairs, the analysis was limited to only those types of flights (Samis, 1985). An earlier study (Campbell, 1977) used official FAA forecasts to generate air passenger demand to cities external to the study area, which also limited the analysis to domestic scheduled air carrier service. Even though MADAM has only been used for domestic scheduled air carrier service in the past, it appears to be capable of handling international flights if the appropriate demand forecasts are available.

Air fare was not considered a factor in airport choice in either of the two applications of MADAM that were reviewed. However, Samis (1985) stated that Version 6 has the capability to model changes in air passenger preferences resulting from differential pricing (fares and fees) using an exponential form similar to the one for differential access times. Presumably the fares and fees being discussed could be related to both ground access or air fares although this feature was not used in either of the two studies that were reviewed.

MADAM is not intended to generate an economically optimum solution. Rather it attempts to model the interaction between airport capacity, air travel demand, and airline scheduling practice. It is a deterministic model rather than stochastic. According to Samis (1985) there are no appropriate statistical tests to evaluate the model because of its structure. The model has to be evaluated by its match with the known baseline conditions.

Another issue with MADAM identified by Samis is the lack of major enhancements to the model to account for changes in the air transportation industry resulting from deregulation. He suggested that the model should be modified to account for two results of deregulation: hub and spoke complexes and competitive air fares. He also suggested that the model should be changed so that regional demand is disaggregated by resident status, trip purpose, or some indicator of the amount of travel funds.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

More recent models to address the interaction between the air passenger airport choice process and the air service that is offered at each airport serving a multiple airport region include models developed for the San Francisco Bay Area by Hansen (1995) and Pels et al. (2003), as well as the SPASM model for the South East and East of England (Halcrow Group et al., 2002) and the RADAM model for Southern California, both of which are discussed below.

APPLICATION TO AIRPORT SYSTEM PLANNING

While the majority of the airport choice models reviewed in this report were developed in an attempt to provide a formal representation of the air passenger airport choice process, and not primarily for use in airport system planning studies, two recent models were developed with this specific purpose. These are the SERAS Passenger Allocation System Model that was developed for the South East and East of England Regional Air Services (SERAS) Study undertaken by the United Kingdom Department of Transport, Local Government and the Regions, and the RADAM model developed for SCAG.

SERAS Passenger Allocation System Model

The objective of the currently on-going SERAS study has been to examine the demand for airports in the South East and East of England through the year 2030 and consider options for providing airport capacity to meet that demand (Halcrow Group, 2002). The principal, although not the only, focus of this study was the need for future airport capacity to serve the London area. In addition to adding runways at existing airports, including London Heathrow, the study also considered the development of entirely new airports.

The SERAS Passenger Allocation System Model (SPASM) has played a central role in this study. The model allocates the demand for air passenger travel between a set of ground origin zones and foreign or domestic destinations to a set of airports in the study region. It also converts the resulting passenger volumes into the associated number of air transport (aircraft) movements at each airport. The basis of the model is a multinomial logit choice model that considers the total generalized cost of using each alternative air route for travel between a given origin and destination zone, where an air route is defined in terms of the airports serving the origin region and destination zone. The generalized cost combines the actual cost and travel time components into a single value for each route, including the costs and travel time involved in the surface access and egress segments of the trip, as well as the air fares and flight time. It applies airport-specific cost penalties to air routes using capacity

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

constrained airports in order to ensure that the total traffic using those airports does not exceed the capacity limits set for each airport.

Travel times are converted to monetary values using assumed values of time that vary by market segment and are based on values calibrated in a previous study by the United Kingdom (U.K.) Civil Aviation Authority (CAA) and then adjusted to reflect changes in the real value of time since the CAA study. These values are also increased for future years in the application of the model. All passengers in a given market segment are assumed to have the same value of time. The generalized cost of the surface access component is derived from the National Airport Accessibility Model, a network based model that generates travel times and costs by road, coach and rail between 455 U.K. zones and the 30 U.K. mainland airports modeled in SPASM. The costs and times are combined using the same values of time used for air travel times.

Separate sub-models have been developed for different market segments, such as long-haul international business travel using scheduled flights, international travel using charter flights, and international travel on low-fare airlines. These sub-models have different calibration coefficients, and some omit the air fare variable. This structure of sub-models does not allow for air passenger choice between the various market segments, but only for the choice of airport given that a particular market segment has been chosen.

The relationship between passenger traffic on a route and the number of air transport movements (flight frequency) is expressed through so-called "Larame" graphs that express the relationship between the number of seats offered per week and the number of aircraft movements. These have been derived from a statistical analysis of the fleet composition on routes of different traffic density performed by the CAA, and reflect the tendency to use larger aircraft as the traffic density increases. Thus as the model allocates more traffic to a route, the weekly flight frequency is increased, which in turn makes that route more attractive through the flight frequency term in the generalized cost.

The effect of changes in the generalized cost of the various routes serving a particular origin and destination zone pair on the total demand between that zone pair for a given market segment is accounted for through an elasticity effect that depends on a value of demand elasticity that is provided by the user. The user can test whether new air service to a particular destination would be viable from an airport where that service is not currently provided. The availability of this new service will attract some passengers from other routes and the model will determine the equilibrium

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

flight frequency (which may be zero if the service is not viable). However, the approach used in the model inherently assumes that the cost of providing air service to the new destination is the same as from the other airports, unless the user exogenously sets a cost penalty for the new service.

Southern California Regional Airport Demand Allocation Model

The Regional Airport Demand Allocation Model (RADAM) developed for SCAG over the past decade has undergone a number of extensions and enhancements since its earlier versions (ATS, 1993; SCAG, 1993). The most recent description of the model that has been identified was prepared in 2002 (SCAG, 2002), though it is very similar to an earlier description (SCAG, 1999).

The available documentation on RADAM does not include many technical details on model form or structure. The model uses a "bottoms up" approach that generates air passenger demand using a geographical zonal system that consists of aggregations of SCAG traffic analysis zones (SCAG, 2002). The approximately 3,000 SCAG traffic analysis zones (TAZs) are grouped into about 100 RADAM analysis zones. Air passenger demand at a zonal level is generated using equations based on socio-economic characteristics of each zone, as well as airport proximity and the level of air service at nearby airports. This allows the model to calculate what is referred to as "catalytic demand", or an increase in demand in a given zone due to changes in employment (and possibly population) resulting from the introduction of new air service at a nearby airport. This is distinguished from "induced demand", which is defined as an increase in trip-making (air travel propensity) by the existing population and businesses due to an improvement in air service at a nearby airport. The model defines three passenger categories: business, pleasure, and all-inclusive tours. Within each passenger category, separate equations are defined for travel by various types of carrier (commuter, large air carrier), length of haul, and international destination. In all, there appear to be ten different market segments used in the model: two commuter, three domestic, and five international.

The model also includes modules to evaluate shifts in passenger demand between regional airports resulting from the introduction of intra-regional high-speed rail systems, to estimate vehicle-miles of highway travel and associated vehicle emissions, and to consider airport capacity constraints. In addition to modeling air passenger demand, RADAM has also been designed to model the distribution of air cargo demand among airports in the region.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

The various descriptions of RADAM refer to the importance of considering traveler perceptions of air service attributes and airport accessibility, as well as such factors as incomplete information or airline loyalty. While these are likely important considerations, the available documentation does not explain how they are addressed within the model. The descriptions refer to "asymmetric logic" as "a method used to mathematically incorporate anomalous survey data in the modeling process, in order to reflect idiosyncratic human behavior." Further information on "asymmetric logic" is not provided.

The model descriptions explain that the demand generation equations consist of a series of MNL (multinomial logit) equations, but further details on the form of the equations and variables used were not provided. One example equation was included in a presentation that was made to a RADAM workshop (SCAG, undated). This suggests that the demand generation equations are MNL equations that express the proportion of the total regional demand in a given passenger type and trip length category that is generated in each zone. These proportions would then be multiplied by the total regional traffic in each category to give the number of passengers in each zone. The available documentation does not explain how the total regional traffic is determined.

The model description explains that the demand generation equations utilize the following variables:

- Total population
- Total employment
- Retail employment
- High-tech employment
- Median household income
- Disposable household income
- Household size
- Number of households
- Licensed drivers per household.

The equation presented at the RADAM workshop is broadly consistent with those listed above; however, the example equation does not include a term for number of households or the number of licensed drivers. In any event, including a term for number of households would be redundant in an equation that included population and household size. In addition to the general terms described above, the example

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

equation also included other terms: the population over 65; a travel time term derived from the ground access mode choice component of the model; an adjustment for special travel generators, such as Disneyland; and a number of air service supply terms. It is unclear whether the differences between the typical terms described in the documentation and the variables in the example equation represent the evolution of the model over time or whether different equations are used to reflect different categories of demand. It appears that demand generation at the zonal level varies inversely with airport accessibility and directly with flight frequency, although it is unclear how this is measured. Since the values of the coefficients of the equation are not given, it is difficult to comment further on the demand generation model structure.

The available documentation provides only limited information on the airport choice component of the model; however, the module relies on the following primary variables:

- Total number of flights
- Frequency of flights
- Non-stop destinations served
- Number of discount airlines
- Travel time from home
- Travel time from work
- Travel time from hotel/convention center
- Ground access congestion
- Air fare
- Terminal congestion and convenience
- Number of gates/gate saturation
- Parking costs and convenience
- Parking saturation
- Central terminal area congestion
- Curbside congestion
- Airport mode choice options.

Many of these primary variables are apparently derived from support modules that include additional sub-variables. It is not possible to comment further on the airport

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

choice module without knowing its functional form, which variables are used for which types of trip, or the calibrated coefficients used in the model.

The model also includes an airport ground access mode choice component, although no details were included in the documentation provided.

The airport demand allocation process proceeds through an iterative process. Flight frequencies at each airport are adjusted for consistency with the air passenger allocation, using assumptions about average aircraft size and load factors. The details of this process are not provided, but a constant load factor is used for all flights in a given market segment. Average aircraft size assumptions vary by length of haul in the various market segments.

In addition to its use in airport system planning for the SCAG region, RADAM has also been used to estimate the economic impacts of developing a new commercial airport at the former El Toro Marine Corps Air Station in Orange County (Erie et al., 1998; Erie et al., 1999; Erie & McKenzie, 2001). This analysis combined the airport demand allocation function of RADAM to estimate the potential volume of air travel that would be attracted to the new airport with the ability of RADAM to estimate the changes in land use that would occur in the vicinity of the new airport. These reports, particularly Erie et al. (1998), provide additional detail on how RADAM calculates induced and catalytic demand. The discussion is qualitative and does not include any equations or coefficient values.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

3 AIRPORT GROUND ACCESS MODE CHOICE MODELS

There were somewhat fewer ground access mode choice models in the recent literature than airport choice models, although some airport choice models include ground access mode choice components, as discussed above, and the ground access mode choice models displayed more variability in the variables that were found to be significant. This made it difficult to derive general conclusions about appropriate model form. However, some common themes were found and some of the variation in model form could be explained by conceptual weaknesses in some of the model formulations as well as the lack of important data in some of the air passenger surveys that were used to develop the models.

IMPORTANT VARIABLES

While the different models included a wide range of variables, some general findings emerged.

Access Time and Cost

These two variables were used in a majority of the models. They were found to be insignificant in only a few models. However these models had other problems, such as poor survey data, that made their results questionable.

Income

Income also appears to be an important variable, but it was only used in the models by Gosling (1984) and Harvey (1987). It is an important variable to consider because it determines the significance of cost in the utility function. For higher income travelers, cost will be less important compared to time in determining modal utility (Gosling, 1984). Both Gosling and Harvey divided their cost variable by income to ensure that higher income diminishes the importance of cost in their models. However, Harvey only did this for non-business travelers because he found that the effect of income on the cost sensitivity of business travelers provided no significant increase in explanatory power, while for non-business travelers it did add substantially to the explanatory power of the model.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Harvey used the following term to express the effect of income on cost:

$$\frac{cost}{(household\ income\ )^{1.5}}$$

although he did not explain why the household income should be raised to the power 1.5. This is an area that needs further study.

Luggage

The amount of luggage carried by an air party can be a strong deterrent to using public transit as an access mode (Harvey, 1986). Harvey found that the implicit price of each additional piece of luggage per person (the fare reduction that would offset the disutility of having to handle the additional luggage) was $11.17 for non-business travelers, which was about 2.4 times the implicit price for business travelers. Of all the ground access mode choice models reviewed, Harvey's model was the only one that considered the effect of luggage, although Gosling (1984) suggested that a refinement to his model would be to include a variable for the number of bags per person.

Gender

In two of the studies, female travelers were assumed to have a higher preference for being dropped off at the airport and for using modes more secure than bus or rail, such as taxis and limousines (Sobieniak, et al., 1979; Harvey, 1988). In both studies, the gender of the traveler was accounted for by using a dummy variable in the utility function.

However, this variable may not be important for the business model. Harvey (1986) found that considering the gender of the traveler is only important for non-business travelers. He stated that non-business female travelers show a strong preference for modes that provide escorted door-to-door service.

These results are intuitive and suggest that it may be useful to include a dummy variable in the utility equation for non-business travelers to account for the gender of the traveler. Another possibility that should be explored is the calibration of separate models for male and female non-business travelers.

POTENTIAL IMPROVEMENTS

The review of past studies suggested a number of aspects where further work might result in improvements to the models.

Perceived Variance in Travel Times

The impact of perceived variance in travel times on access mode choice has not been addressed in any of the models, but could be an important factor. Work by Leake and Underwood (1977) illustrates that the travel time, travel cost, and income variables do not explain the behavior of air travelers as well as rail travelers. This suggests that there may be factors specific to air travelers not included in typical utility functions. One such factor may be the perceived variance in travel times to the airport. This factor could also be explained as the utility (security) derived from using the same mode as in previous trips, and therefore the greater ability to predict the arrival time at the airport.

Lower variance in travel time to the airport may be more important to air travelers than shorter travel times, due to the relatively low frequency of departures in many markets and therefore the greater inconvenience of missing a flight. If this were true, then there should be noticeably different behavior by short-haul and long-haul travelers. Long-haul travelers should demonstrate a higher likelihood of using the familiar modes and place less importance on travel time and cost differences between the modes. There may also be different behavior by business and non-business travelers, with business travelers more concerned about expected travel time and non-business travelers more concerned about travel time variance. If these assumptions are true, then the difference in behavior should be especially pronounced when comparing short-haul business and long-haul non-business travelers.

The importance of variation in travel time could be studied by examining the arrival profiles of passengers at airports (in terms of the time before flight departure) as a function of access mode, time of day, and travel destination.

Access and Egress Trips

Because survey data is usually obtained from enplaning passengers, there is a lack of information about the trip from the airport. Most models, therefore, only include the trip to the airport. However, it is important to consider the complete tour if the effectiveness of a new access mode is to be determined. Ellis (1974) developed the only model that accounted for trips from the airport. Different sets of coefficients were calibrated for trips to and from the airport as well as for business and non-

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

business trips. The distinction between trips to and from the airport and between business and non-business trips cause about the same differences in the coefficients.

Automobile Operating Costs

Gosling (1984) suggested that in order to capture the difference between perceived and actual automobile operating costs, the cost should be expressed in terms of travel time rather than assuming a cost per mile for operating the automobile. The calibrated parameter will thus determine the perceived cost.

There are two issues that arise with this approach. The first is that travel time is usually already included in the utility function. Therefore the model specification needs to provide a way for the travel time coefficient for those using automobile to be different from those using other modes, so that its value can include the perceived operating cost. Where the automobile is only used for part of the trip to the airport (such as access to a remote terminal), the travel time will need to be split between two different variables that can take different coefficients. Separate coefficients will also be required for drop-off trips where the vehicle is not parked for the duration of the air trip, to account for the additional costs (and travel time) of the return trip by the driver.

The second issue arises where the utility function includes the household income of the air party, as discussed above. If income is not also included in the automobile operating cost term, this implies that the perceived cost increases with income. This may be reasonable if higher income households operate more expensive vehicles, although there appears to have been no empirical work done to explore whether observed behavior supports this view.

Passenger Awareness of Ground Access Alternatives

All of the models examined in this review implicitly assume that the traveler has full information about the existence and service attributes of all available modes. Spear (1984) suggested that models should be calibrated using data on passenger awareness of ground access alternatives. This would allow analysis of how better marketing would affect ridership.

Type of Non-Business Travel

Harvey (1988) suggested expanding the range of typical air traveler categories to include a distinction between vacationers and those visiting friends and relatives, as vacationers are much less likely to be dropped off at the airport in a personal

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

automobile. Another way of handling this would be to include a dummy variable in the utility function for nonresident drop-off trips that is zero if the trip origin is the home of a friend or relative, or a large negative value otherwise (Gosling, 1984). This would effectively eliminate the option of being dropped off at the airport for those nonresident passengers who are not visiting residents of the region.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

4

AIR PASSENGER TRIP GENERATION MODELS

The ability to model how air passenger demand is distributed across the different airports in a multi-airport region requires a detailed understanding of where the air party trips begin and end in the region. While this can be determined for some time in the past from air passenger survey data, there are at least two reasons why a more formal air passenger trip generation model is necessary:

1. Any air passenger survey is only a sample of all trips. The fact that some percent of survey respondents came from a particular zone or that the survey respondents from a particular zone had a certain distribution of air party characteristics does not mean that the same percent of all air passengers come from that zone, or that all air parties from that zone have the same distribution of characteristics.

   In the case of large urban regions, such as Southern California, there are typically several thousand traffic analysis zones. Even a large sample air passenger survey will not include enough responses to ensure an accurate sample of air party trips from every zone.

   In many multi-airport regions there is also the problem that air passenger surveys at different airports have often been undertaken at different points in time and with different sample sizes and sampling strategies (and sometimes even different survey question wording). While adjustments can be made to integrate the results of these surveys into a single estimate of air party trip end distribution in the region, this process can be prone to error.

2. It is necessary to have a means to predict how the distribution of air travel trip ends will change in the future as the demographic and land-use patterns evolve in the region.

Unfortunately, this aspect does not appear to have received very much attention in the literature. The topic was addressed in an early National Cooperative Highway Research Program (NCHRP) report (Keefer, 1966), but there has been very little work since. The study used home interview survey data for several large metropolitan regions to determine airport trips per thousand population in terms of distance from the airport. The results show that trip generation rates decline with distance from the airport, with air travel trip generation rates becoming relatively constant beyond about 5 miles from the airport.

However, these results are biased by the data collection method, since home

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

interview surveys exclude many visitors to the region (those who stay in hotels) and it is unclear how respondents would have answered regarding trips made by visitors who stayed in their home. Furthermore, distance from the airport is a poor way to capture income and other socio-economic factors that influence air passenger trip generation. In any event, the data is now very old and air travel propensity has changed considerably in the past 40 years.

Another study from the same period (Keller, 1966) considered the variation in air passenger trip generation rates in different counties in West Virginia, but did not correlate this with any socioeconomic factors. A more recent study (Ruhl & Trnavskis, 1998) examined the total number of air passenger trips generated at different airports in terms of the population of the region served by the airport, but did not consider zonal differences in this rate within each region.

The most comprehensive study of air passenger trip generation rates in a metropolitan region that has been identified was performed as a graduate student project at the University of California, Berkeley, and examined trip generation rates in the Southern California region (Picado, 1994). The study used data from air passenger surveys performed at Los Angeles International, Ontario International, and Burbank airports to develop an integrated database of air trip origins on a zonal basis, dividing the region into 65 analysis zones, and then estimated trip generation models in terms of population, households, income and employment at the zonal level. The analysis developed separate models for resident and visitor trips, and further subdivided the visitor trips into those staying in hotels and those staying with local households. However, the trip generation models did not distinguish between business and non-business trips.

The published documentation on the Regional Airport Demand Allocation Model (RADAM) developed for the Southern California Association of Governments (SCAG) provides little technical information on the trip generation component of the model. On the basis of information presented at a RADAM workshop (SCAG, undated), it appears that this component consists of a logit choice model that distributes the total regional demand for each of a number of defined categories of passengers among the analysis zones in the region on the basis of the socioeconomic characteristics of the zones. This is analogous to assuming that air passengers "choose" their zone of trip origin or destination in the region on the basis of the zonal characteristics. This approach has the advantage that it automatically ensures that the total number of trips generated by all the zones in the region for a given category of passenger sums to the exogenously determined control total for the region. However, the use of a choice model paradigm implies that the number of trips generated by a

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

given zone depends not only on the characteristics of that zone, but also on the characteristics of the other zones. While this may be a fair representation of how vacationers choose among different ground zones, it is not necessarily appropriate for residents since it is unlikely that the number of trips generated by the population of a particular zone would be influenced by changes in the socioeconomic characteristics of other zones in the region.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

5 AIR SERVICE FORECASTING MODELS

All air passenger demand allocation models include some measure of air service at the different airports in the region. Typically this is some function of the flight frequency in the market in question. Some studies have also attempted to include a measure of air fare differences at different airports, although generally this has been less successful. Clearly, such differences in air service are an important determinant of why some airports in a region attract a large market share and others do not.

However, this poses a challenge for the use of airport demand allocation models to predict the future distribution of demand among the various airports in a multiple airport region. While the past pattern of air service can be obtained from standard industry sources, such as the Official Airline Guide and (at least in the United States) the traffic and fare statistics reported to the U.S. Department of Transportation by the airlines, what is needed for forecasting is the future pattern of air service.

This is not independent of the airport choice behavior of the air passengers, of course. The more passengers that choose to use a particular airport, the more frequency the airlines can afford to offer in that market, and in turn the more attractive the airport will become to potential travelers. Thus a positive feedback process exists between the airport choice process and the air service offered (Hansen, 1995). At the same time, whether an airline decides to expand or reduce service in a particular market from a given airport will depend not only on the passenger traffic but also on the average yield that can be obtained in the market, as well as the costs of using the airport in question. In general, higher costs can be tolerated at airports that are able to attract a large share of the market (Pels, et al., 1997). Recently, the decisions by low-cost airlines to enter markets by starting or expanding service from smaller secondary airports, rather than compete directly with established carriers at the primary airport, has become a significant factor in the growth of the secondary airports. This in turn generates a competitive response from the established carriers (Windle & Dresner, 1999).

Thus developing a model to predict future levels of air service at airports in a region will require the ability to capture these feedback and economic effects, as well as the associated airline decision making. This is no small challenge, and perhaps not surprisingly, there appear to be very few studies that have attempted to develop such a model. There are, however, a large number of studies that have looked at various aspects of the problem, such as factors that influence airline market share (Proussaloglou & Koppelman, 1995; Suzuki et al., 2001) and how air travelers choose between the available airlines, flights and fare class options in a given market (Alamdari & Black, 1992; Proussaloglou & Koppelman, 1999; Wojan, 2002).

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Only two formal models have been identified in the literature that attempt to integrate the air passenger airport choice process with a prediction of the level of air service offered at each airport in a multiple airport system. Hansen (1995) developed a model to predict the distribution of passengers in a given air service market (trip destination) among multiple airports taking into account the feedback between passenger choice and flight frequency, and applied this to the three commercial airports in the San Franscisco Bay Area. However, the model does not explicitly incorporate any direct measure of air service, but uses the passenger traffic as a surrogate for the flight frequency. Furthermore, it does not consider the effect of air fare differences between airports. Pels et al. (1998) developed a model that also considers the passenger airport choice process as well as airline competition, and uses this to determine the profit maximizing flight frequencies and air fares in a given market. However, the analysis was performed under the assumption that each airline has an identical cost structure, the number of airlines serving each airport is known (and fixed), and the total passenger demand is independent of either air fare or flight frequency.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

6 LOCAL PLANNING AGENCY AIRPORT GROUND ACCESS MODELING

This discussion briefly surveys some of the airport ground access modeling techniques that are currently being used by local planning agencies, such as metropolitan planning organizations (MPOs), state departments of transportation (DOTs), cities, and transit providers. For the most part, because airport ground access trips are only a small subset of the travel that these agencies need to analyze, the techniques being used are not as rigorous or data intensive as many of the research efforts described in the literature review.

Public agencies model airport ground access for a variety of reasons and end-uses, including:

- As a component of a regional travel demand model;
- As a component of an analysis of a corridor or a proposed transportation improvement that would affect airport access trips; and
- As a component of an analysis of intercity travel (generally high speed rail or maglev analyses).

To achieve these modeling purposes, planners have had to perform (at least to some degree) many of the same types of modeling analyses that are required for the SCAG Regional Airport Model effort, including:

- Air passenger trip generation models;
- Airport ground access mode choice models;
- Airport choice models; and
- Air service forecasting models.

Table 6-1 summarizes how these model components tend to overlay with models of each purpose. Some of the current practices being employed for each of these broad objectives are then described below.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Table 6-1 Summary of Common Model Treatments

	Regional Models	Corridor Study Models	Intercity Models
Trip Generation	Modeled explicitly (approaches discussed below)	Modeled explicitly (approaches discussed below)	Modeled explicitly (approaches discussed below)
Access Mode Choice	Modeled explicitly (approaches discussed below)	Modeled explicitly (approaches discussed below)	Modeled implicitly as part of model system (discussed below)
Airport Choice	Not modeled: Airport-specific demand treated exogenously / as an input	Not modeled: Airport-specific demand treated exogenously / as an input	Modeled implicitly as part of model system (discussed below)
Air Service Forecasting	Not modeled: Air service levels treated exogenously / as an input	Not modeled: Air service levels treated exogenously / as an input	Analyzed among forecasting scenarios

REGIONAL TRAVEL DEMAND MODELS

As noted in the table above, almost all regional travel demand models use estimates of air passenger demand as inputs to the model system, rather than as model outputs or interim findings. Regional modelers usually obtain base year air passenger estimates from airport authorities, and either obtain air passenger forecasts from the airport authorities or else apply annual passenger growth rates to obtain forecasts. These growth rates are either extrapolated from past air passenger growth or are developed from projected overall growth in the region (economic growth or projected travel growth from other components of the regional travel model). Air service levels affect the projected air passenger demand only to the extent that airport authority forecasts reflect the relationship.

Interestingly, these practices seem to be generally followed individually for each airport in regional models covering areas with more than one major airport. Therefore, potential competition for passengers between airports within a region and airport choice are not elements of most regional models.

In regional models, the overall air passenger demand for airports set the number of airport trips generated within the region. In most model systems, airports are treated as “special generators,” meaning that the number of passenger trips attracted to the airports is calculated separately from the regional model’s trip attraction equations. Airport employee trips are frequently included in the general trip attraction models.

The challenge for the model systems is then to model from and to where in the region these trips go. Several approaches are used to accomplish this.

One common approach is to treat airport passenger trips as part of other model system trip purposes, such as the “Home-based Other” or “Home-based Nonwork”

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

and "Non-home Based" trip purposes. Since airport passenger trips are usually included in household travel surveys and other model input data sets, these trips can appropriately be combined with these other purposes for the model. Many model systems then model the airport passenger trip ends as part of the standard purpose-specific trip distribution process, usually involving the application of the gravity model to the base year network travel times and travel survey data.

Some model systems classify the trips under these general modeling purposes, but use a separate trip distribution mechanism for modeling the airport passenger trips, relying on base year airport access survey data. The airport trips are then folded into the other trips of relevant purposes to ensure that trips are not double counted. The airport trip distribution model can be formulated as a separate gravity model.

Another alternative is to treat the airport passenger trips as a completely separate case from the other model purposes. One model system is said to keep separate trip purposes for Home-based airport passenger trips and Non-home based airport passenger trips. This model system includes a separate trip generation/distribution model for airport trips, and then uses this model to estimate forecast year airport trips. The model was developed based on household travel survey data. Another model system applies an origin probability model to air passenger trips. This model predicts the probability that a given air passenger trip will begin in a specific model zone based on traveler and zone characteristics.

Regional models vary in terms of how they model airport access mode choice. Some regions simply factor the total air passenger trips to vehicle trips based on base year data, and convert person trips to vehicle trips for the regional model's highway assignment. Most of the model systems that classify the airport passenger trips into the Home-based Other and Non-home based purposes simply apply the mode choice models used for the purposes as a whole to the airport passenger trips.

A few regional models do reflect the fact that the choice set for modes of airport access is different than for other trips within the region through the application of airport passenger airport access mode choice models. These models are formulated as multinomial logit or nested logit models, and are estimated from base year network data and airport access surveys. Independent variables for the models include traveler characteristics, trip characteristics, and modal levels-of-service.

CORRIDOR STUDY MODELS

Several recent and ongoing major corridor studies have analyzed airport access trips as an important travel market segment. Many cities have existing rail transit access to airports, and therefore have been the subject of mode choice analyses of various kinds. In addition, EIS and MIS analyses involving improved airport access have been recently or are currently being conducted in a very large number of cities. For these studies, air passenger trip generation is generally modeled through:

- The application of the regional models,
- The development of techniques like those described above for regional models, or
- The direct expansion of base year airport access survey data and the application of growth rates.

Corridor studies often apply the regional model techniques to airport access mode choice modeling as well, but many corridor analysts often develop new airport-passenger-specific access mode choice models. The standard modeling technique is to use multinomial or nested logit models, and to estimate models based on regional model network data and airport access survey data.

INTERCITY TRAVEL DEMAND MODELS

Recent intercity travel demand models have used several different approaches to modeling the different elements of travel that the SCAG model will need to handle. Of particular relevance to the SCAG modeling effort is the intercity travel demand model system developed for the California Intercity High Speed Rail Commission by Charles River Associates. This model system consists of the following model components:

- "Total Travel Demand Models" that predict the total region-to-region demand for intercity air and auto trips.
- Zone allocation models that assign the forecast regional trip ends to specific analysis zones.
- "Mode Diversion Models" that predict how many air, rail, and auto trips would instead be made by a new high speed rail service.
- Intercity induced demand model.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

The air total travel demand model is used to forecast future year region-to-region air trips in the study area in the absence of rail improvements. The model is a time series regression model that relates air trips for each region-to-region pair to regional socioeconomic variables, air levels of service, and dummy variables for different regional pairs. The model was estimated from data for the period 1982 to 1992.

The next step of the high speed rail model system is to allocate the forecast trip ends to smaller zones within the regions. The model has 47 zones in the Los Angeles area. Air trip ends are allocated to specific zones using information from an air passenger intercept survey. First, the total number of air trips are broken into business and nonbusiness purposes based on the survey proportion. For each purpose, the distributions among the types of trip ends (home, workplace, hotel) were calculated, and corresponding zonal variables were used to allocate the trip ends. The zonal variables used to allocate the trips were total employment, number of hotel rooms, and an income weighted population measure.

The intercity mode diversion model is used to forecast the demand for high speed rail service. The model analyzes overall intercity mode choice, but includes both line-haul modal levels-of-service and station/airport access levels-of-service as independent variables. The model does not distinguish between alternative access modes, and instead uses approximate auto times and costs as the access service levels. Because the model does not include access submode analysis, it is not directly applicable to the SCAG Regional Airport analysis, but the model does provide implied marginal rates of substitution (such as value of time estimates) for intercity travel in California.

The California High Speed Rail Study did not include the means to analyze airport choice. All travelers from specific analysis zones are assigned to the airport and high speed rail station with the lowest generalized cost (based on the mode choice model utility equation). The model system does not include an intercity service prediction model either. However, the induced demand component of the model does provide a means of relating overall intercity travel to improvements in intercity service. As with the mode choice model, the induced demand model does provide guidance into expected relationships for California travelers, but the model component is not likely to be useful for the SCAG Regional Airport modeling effort.

Cambridge Systematics has applied an alternative approach to forecasting intercity travel demand that while less relevant geographically may be valuable in terms of the procedures used. For these studies, three separate disaggregate categories of models were estimated and linked through the use of inclusive term (logsum) values.

The three categories of models can be summarized as follows:

1. The mode/route choice models relate travelers' choice of a mode to the level of service and price attributes of the competing options;
2. The destination choice models relate travelers' choice of a destination to attributes of the destination and the level of service provided to each destination; and
3. The trip frequency models relate the number of trips taken by different travelers to their socioeconomic characteristics and the overall accessibility offered by the transportation system.

The first set of models developed were the mode choice models. These models seek to explain base-year travel by mode as a function of the levels of service of the different modes, characteristics of the travelers, and characteristics of the trips being made. The mode choice models are a group of market segment-specific nested logit models that were developed from new survey data and other data sources. The output of the model development effort was a set of utility equations for each mode option. These utilities were compared to each other to develop estimates of the probabilities of mode usage for individuals making particular types of trips.

The second set of models that were developed are the destination models. These models relate travelers' destination choices to the characteristics of their households, the attractiveness or size of each destination, and the relative differences in the travel impedance to each destination.

The destination choice models are a group of market segment-specific multinomial logit models that simulate the choice among potential destinations. The models were developed using newly collected household survey data, base-year measures of the size and relative attractiveness of the destination zones, and measures of multimodal impedance between zones as provided by the mode choice models.

The third set of models are the trip frequency models. These models relate travelers' trip frequency by trip type and party size to characteristics of their households and to the overall accessibility of their homes to potential trip destinations. The models are multinomial logit models with the choices being specific numbers of trips of a certain type by party size. The models were developed with the new household survey data and results of the destination choice models.

An advantage of the model system is that it integrates the forecasts of diverted trips and generated trips by using models that are linked to each other. Information from the mode/route choice models is used in the destination model, and information from the destination model is used in the trip frequency model. Therefore, projections of the different components of travel are consistent with each other.

Another advantage of the approach is that it relies on fairly sophisticated statistical estimation procedures that are rooted in microeconomic consumer theory, but that can be applied effectively without a detailed knowledge of the estimation procedures. The model system has been installed in a spreadsheet environment that easily can be mastered.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

7 IMPLICATIONS FOR THE SCAG REGIONAL AIRPORT DEMAND MODEL

In spite of the importance of airport choice and airport ground access mode choice in the airport planning process, past attempts to model these choice processes do not yet appear to have developed a clear consensus on detailed functional forms for the models or variables to be included.

The literature indicates that there is growing agreement that the nested logit model appears to have the most appropriate structure for analyzing airport choice and ground access mode choice. Travelers should be classified into categories by both trip purpose and resident or non-resident status for best use of this model form. Other non-traditional classifications, such as by length of haul, should also be studied, because of the limited treatment of different classifications in the literature and their potential for explaining some of the variations in mode choice that cannot be explained by traditional variables. For airport choice, variables accounting for air fare, flight frequency, and overall ground access service have been effective. For ground access mode choice, variables accounting for travel time, travel cost, and income have been shown to be important. Other variables, such as the amount of luggage and the gender of the traveler have been shown to influence the use of public transportation modes.

However, partly as a result of differences in functional form and partly as a result of differences in the datasets used to calibrate the models, there is very little consistency in the parameter values estimated across the different models. Thus it is unclear whether there is an underlying behavioral pattern that is consistent across different communities and situations. This makes the transferability of any of the models extremely questionable.

For both types of model, there is a need to experiment with new variables in the utility functions and to attempt to resolve the inconsistent results presented in the literature. New variables would be especially useful if they address aspects of the choice process that are likely to be influenced by different ground access policy alternatives, such as travel time reliability, walking distance involved in connections between public transportation modes, or the ability to check baggage at off-airport locations.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

In contrast to airport choice and airport ground access mode choice, very little work appears to have been done to model air passenger trip generation at the zonal level, or to forecast how air service can be expected to evolve in a multiple airport region. Since both aspects are critical to the process of modeling the future allocation of air passenger demand in a multiple airport region, there are aspects that will require careful attention in the development of the regional airport demand model.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

REFERENCES

AIRPORT DEMAND ALLOCATION MODELS

Abbas, Mahmoud S., Airport Choice: An Empirical Study of the Determinants of Demand for Local Air Service, Dissertation UCB-ITS-DS-90-1, Institute of Transportation Studies, University of California, Berkeley, 1990.

Advanced Transportation Systems, RADAM: Regional Air Passenger Demand Allocation Model, Version 3.1, Venice, California, 1993.

Al Chalabi, Suhail, and Saleh Mumayiz, Allocation of Enplanement Forecasts to Alternative Airports, Working Paper No. 10, Illinois-Indiana Regional Airport Site Selection Report, Appendix A, Prepared for the State of Illinois, State of Indiana and City of Chicago, TAMS Consultants, Inc., Chicago, November 1991.

Ashford, Norman, and Messaoud Benchemam, "Passengers' Choice of Airport: An Application of the Multinomial Logit Model," Transportation Research Record, Number 1147, 1987.

Ashford, Norman, "Predicting the Passengers' Choice of Airport," Airport Forum, Vol. 19, No. 3, June 1989.

Augustinus, J.G., and S.A. Demakopoulos, "Air Passenger Distribution Model for a Multiterminal Airport System," Transportation Research Record, Number 673, 1978.

Basar, G., and C.R. Bhat, A Parameterized Consideration Set Model for Airport Choice: An Application to the San Francisco Bay Area, Technical Paper, Department of Civil Engineering, The University of Texas at Austin, August 2002.

Bondzio, Lothar, "Study of Airport Choice and Airport Access Mode Choice in Southern Germany," in Seminar K: Airport Planning Issues, Planning and Transportation Research and Computation (International) Co., 24th Annual Meeting, Brunel University, 1996.

Bradley, Mark A., "Behavioral Models of Airport Choice and Air Route Choice," in Juan de Dios Ortuzar, David Hensher and Sergio Jara-Diaz (eds.), Travel Behavior Research: Updating the State of Play (chapter 9), Elsevier, Amsterdam, 1998.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Campbell, B., Multiple Airport Demand Allocation Model, Report FAA-AVP-77-39, Federal Aviation Administration, Washington, D.C., September 1977.

Erie, Steven P., John Kasarda and Andrew McKenzie, A New Orange County Airport at El Toro: An Economic Benefits Study, Prepared for the Orange County Business Council, California, October 1998.

Erie, Steven P., John D. Kasarda, Andrew M. McKenzie and Michael A. Molloy, A New Orange County Airport at El Toro: Catalyst for High-Wage, High-Tech Economic Development, Prepared for the Orange County Business Council, California, December 1999.

Erie, Steven P., and Andrew M. Mckenzie, A New Orange County Airport at El Toro: A 2001 Update of Economic Impacts, Prepared for the Orange County Business Council, California, October 1998.

Furuichi, Masahiko, and Frank S. Koppelman, "An Analysis of Air Travelers' Departure Airport and Destination Choice Behavior," Transportation Research, Vol. 28A, No. 3, May 1994.

Halcrow Group Ltd. and Scott Wilson Kirkpatrick & Co. Ltd., Rules and Modelling: A Users Guide to SPASM, Prepared for the Department of Transport, Local Government and the Regions, South East and East of England Regional Air Services Study, London, England, January 2002.

Halcrow Group Ltd., SPASM Runs for SERAS: Input Assumptions and Model Outputs, Prepared for the Department of Transport, Local Government and the Regions, South East and East of England Regional Air Services Study, London, England, April 2002.

Harvey, Greig, "Airport Choice in a Multiple Airport Region," Transportation Research, Vol. 21A, No. 6, November 1987.

Harvey, Greig, ACCESS: Models of Airport Access and Airport Choice for the San Francisco Bay Region – Version 1.2, Report prepared for the Metropolitan Transportation Commission, Berkeley, California, December 1988.

Innes, J. David, and Donald H. Doucet, "Effects of Access Distance and Level of Service on Airport Choice," Journal of Transportation Engineering, Vol. 116, No. 4, July/August 1990.

Mandel, Benedikt N., "The Interdependency of Airport Choice and Travel Demand," in Marc Gaudry and Robert Mayes (eds.), Taking Stock of Air Liberalization (chap. 13), Kluwer Academic, Boston, Massachusetts, 1999.

Monteiro, Ana B., and Mark Hansen, "Improvements to Airport Ground Access and the Behavior of a Multiple Airport System: BART Extension to San Francisco International Airport," Transportation Research Record, Number 1562, November 1996.

Pels, Eric, Peter Nijkamp and Piet Rietveld, "Access to and Competition between Airports: A Case Study for the San Francisco Bay Area," Transportation Research, Vol. 37A, No. 1, January 2003.

Samis, Robert, Multiple Airport Demand Allocation Model (MADAM) Calibration and Sensitivity Analysis, National Capital Region Transportation Planning Board, Metropolitan Washington Council of Governments, Washington, D.C., August 1985.

Southern California Association of Governments, Air Passenger Demand Allocation to Military Air Bases, Los Angeles, California, April 1993.

Southern California Association of Governments, Regional Airport Demand Allocation Model (RADAM) Workshop, Presentation slides, Los Angeles, California, undated.

Southern California Association of Governments, RADAM Model Description, Presentation to the Aviation Technical Advisory Committee, Los Angeles, California, March 11, 1999.

Southern California Association of Governments, RADAM Airport Demand Allocation

Model – Basic Description, A Discussion Paper for the SCAG Aviation Task Force RADAM Model Workshop, Los Angeles, California, October 17, 2002.

Windle, Robert, and Martin Dresner, "Airport Choice in Multi-Airport Regions," Journal of Transportation Engineering, Vol. 124, No. 4, July/August 1995.

AIRPORT GROUND ACCESS MODE CHOICE MODELS

Chebli, Hussein, and Hani S. Mahmassani, Air Travelers' Stated Preferences Towards New Airport Landside Access Mode Services, Paper presented at the Transportation Research Board Annual Meeting, Washington, D.C., January 2003.

Ellis, R.H., J.C. Bennett and P.R. Rassam, "Approaches for Improving Airport Access," Transportation Engineering Journal, Vol. 100, No. TE3, August 1974.

Gosling. Geoffrey D., An Airport Ground Access Mode Choice Model, Technical Document UCB-ITS-TD-84-6, Institute of Transportation Studies, University of California, Berkeley, July 1984.

Halcrow Group Ltd., SERAS Surface Access Modelling, Prepared for the Department of Transport, Local Government and the Regions, South East and East of England Regional Air Services Study, London, England, July 2002.

Harvey, Greig, "A Study of Airport Access Mode Choice," Journal of Transportation Engineering, Vol. 112, No. 5, September 1986.

Howard Humphreys and Partners, Heathrow Surface Access Study, Report prepared for the U.K. Department of Transport, Leatherhead, Surrey, England, June 1987.

Leake, G.R., and J.R. Underwood, "An Inter-City Terminal Access Modal Choice Model," Transportation Planning and Technology, Vol. 4, No. 1, September 1977.

Lythgoe, W.F., and M. Wardman, "Demand for Rail Travel to and from Airports," Transportation, Vol. 29, No. 2, May 2002.

Psaraki, Voula, and Costas Abacoumkin, "Access Mode Choice for Relocated Airports: The New Athens International Airport," Journal of Air Transport Management, Vol. 8, 2002.

Sobieniak, J., R. Westin, T. Rosapep and T, Shin, "Choice of Access Mode to Intercity Terminals," Transportation Research Record, Number 728, 1979.

Spear, Bruce D., An Analysis of the Demand for Airport Bus Services at Washington National and Dulles Airports, Report DOT-TSC-FAA-84-2, U.S. Department of Transportation, Transportation Systems Center, Cambridge, Massachusetts, May 1984.

Tambi, John E., and John Falcocchio, Implications of Parking Policy for Airport Access Mode Choice, Paper presented at the 70th Annual Meeting of the Transportation Research Board, Washington, D.C., January 1991.

AIR PASSENGER TRIP GENERATION MODELS

Keefer, Louis E., Urban Travel Patterns for Airports, Shopping Centers, and Industrial Plants, National Cooperative Highway Research Program Report 24, Highway Research Board, Washington, D.C., 1966.

Keller, Charles R., Commercial Air Travel in West Virginia: Trip Generation and Attraction, Master of Science Thesis, West Virginia University, Morgantown, West Virginia, 1966.

Picado, Rosella, Air Trip Generation Model for Southern California, CE299 Report, Submitted for partial fulfillment for the requirements for the Master of Engineering degree, Department of Civil Engineering, University of California, Berkeley, March 1994.

Ruhl, Terry A., and Boris Trnavskis, "Airport Trip Generation," ITE Journal, Vol. 68, No. 5, May 1998.

Southern California Association of Governments, Regional Airport Demand Allocation Model (RADAM) Workshop, Presentation slides, Los Angeles, California, undated.

AIR SERVICE FORECASTING MODELS

Adler, Nicole, and Joseph Berechman, "Measuring Airport Quality from the Airlines' Viewpoint: An Application of Data Envelopment Analysis," Transport Policy, Vol. 8, No. 3, July 2001.

Alamdari, Fariba E., and Ian G. Black, "Passengers' Choice of Airline under Competition: The Use of the Logit Model," Transport Reviews, Vol. 12, No. 2, April-June 1992.

Fujii, Edwin T., Eric Im and James Mak, "Airport Expansion, Direct Flights, and Consumer Choice of Travel Destinations: The Case of Hawaii's Neighbor Islands," Journal of Travel Research, Vol. 30, No. 3, Winter 1992.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Hansen, Mark, "Positive Feedback Model of Multiple-Airport Systems," Journal of Transportation Engineering, Vol. 121, No. 6, November/December 1995.

Pels, Eric, Peter Nijkamp and Piet Rietveld, "Substitution and Complementarity in Aviation: Airports vs. Airlines," Transportation Research, Part E, Vol. 33, No. 4, December 1997.

Pels, Eric, Peter Nijkamp and Piet Rietveld, "Airport and Airline Competition in a Multiple Airport Region: An Analysis Based on the Nested Logit Model," in Airport Facilities: Innovations for the Next Century, Proceedings of the 25th International Air Transportation Conference, Austin, Texas, American Society of Civil Engineers, Reston, Virginia, 1998.

Proussaloglou, Kimon, and Frank S. Koppelman, "Air Carrier Demand: An Analysis of Market Share Determinants," Transportation, Vol. 22, 1995.

Proussaloglou, Kimon, and Frank S. Koppelman, "The Choice of Air Carrier, Flight, and Fare Class," Journal of Air Transport Management, Vol. 5, 1999.

Suzuki, Yoshinori, John E. Tyworth and Robert A. Novack, "Airline Market Share and Customer Service Quality: A Reference-Dependent Model," Transportation Research, Vol. 35A, No. 9, November 2001.

Windle, Robert, and Martin Dresner, "Competitive Responses to Low Cost Carrier Entry," Transportation Research, Vol. 35E, No. 1, March 1999.

Wojan, Oliver W., "The Impact of Passengers' Preferences regarding Time and Service Quality on Airline Network Structure," Journal of Transport Economics and Policy, Vol. 36, No. 1, January 2002.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

APPENDIX A

ANNOTATED BIBLIOGRAPHY

AIRPORT DEMAND ALLOCATION MODELS

Abbas, Mahmoud S., Airport Choice: An Empirical Study of the Determinants of Demand for Local Air Service, Dissertation Series UCB-ITS-DS-90-1, Institute of Transportation Studies, University of California, Berkeley, 1990.

The purpose of this dissertation was to identify the factors that affect the choice of departure airport by business travelers near a small community airport within the sphere of influence of a hub airport. Abbas considered the importance of airport supply variables (e.g. frequency of direct flights, air fare and parking costs) and characteristics of air travelers (e.g. industry type and job type) in determining the choice of airport. Air travel surveys were performed at airports in Bakersfield and Redding, California to develop a database for analysis.

Two methods were used to determine the importance of variables: factor analysis and discriminant analysis. The objective of factor analysis is "to explain the correlations or covariances between a set of variables (departures, fares, access time, access cost, firm size, firm function, traveler's age and income) in terms of a limited number of unobservable, latent factors. These latent factors may not necessarily be mathematically expressed as linear combinations of the original variables."

Discriminant analysis was used as a "classification technique." The airport supply variables that were identified from the factor analysis were used to develop classification functions which allow the classification of travel parties into groups (potential departure airports). For each group, the variables were combined in a linear function which represented the probability of membership in that group. The air travel party is assigned to the group (airport) with the highest probability. "Hence, classification, as used here, means the process of identifying the likely departure airport a traveler may choose when the only information known is the value of the variables representing the level of service at an airport."

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Bakersfield travelers were assumed to choose between either using the local airport or taking surface transportation to Los Angeles International. The probability of making either choice was given by a linear combination of the explanatory variables, as follows:

$$\text{PBFL} = -3.160 + (0.024)\text{FQFS} - (0.001)\text{FQSS} - (0.011)\text{FQTS} + (0.027)\text{OWYFARE} + (0.062)\text{ARPTPKC}$$

$$\text{PLAX} = -6.833 + (0.057)\text{FQFS} - (0.013)\text{FQSS} - (0.026)\text{FQTS} + (0.033)\text{OWYFARE} + (0.184)\text{ARPTPKC}$$

where

PBFL = Probability of the traveling party choosing Bakersfield Airport

PLAX = Probability of the traveling party choosing Los Angeles International Airport

FQFS = Departure frequency of first segment of flight

FQSS = Departure frequency of second segment of flight

FQTS = Departure frequency of third segment of flight

OWYFARE = One-way fare

ARPTPKC = Airport parking cost (dollars)

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Redding travelers were assumed to choose between either using the local airport or taking surface transportation to either San Francisco International Airport or Sacramento Metropolitan Airport. The probability of making each choice was also given by a linear combination of the explanatory variables, as follows:

$$PRDD = -3.990 + (0.026)FQFS + (0.006)FQSS + (0.033)OWYFARE + (0.066)GACCTC$$

$$PSFO = -60.12 + (0.166)FQFS + (0.001)FQSS + (0.023)OWYFARE + (1.625)GACCTC$$

$$PSMF = -10.73 + (0.038)FQFS + (0.002)FQSS + (0.026)OWYFARE + (0.614)GACCTC$$

where

PRDD	=	Probability of the traveling party choosing Redding Airport
PSFO	=	Probability of the traveling party choosing San Francisco International Airport
PSMF	=	Probability of the traveling party choosing Sacramento Metropolitan Airport
GACCTC	=	Airport ground access travel cost (dollars)

and the other variables were defined as before.

The results of the study showed that airport choice for small communities is a supply-driven decision and much less dependent on the socioeconomic characteristics of travelers. There were significant differences among travelers in terms of industry type, firm function, and job function but these differences did not appear to have a significant effect on choice.

From the discriminant analysis, the two most important variables were departure frequency and air fare for both Bakersfield and Redding. Airport parking cost was also important at Bakersfield, while at Redding the next most important variable was ground access travel cost. The factor analysis also identified traveler age and income as possibly explaining some of the variation in the data.

Advanced Transportation Systems, RADAM: Regional Air Passenger Demand Allocation Model, Version 3.1, Venice, California, 1993.

This report describes an early version of an air passenger demand allocation model that was developed to predict the distribution of air passengers between existing and proposed new airports in Southern California. According to the report, RADAM models the air passenger airport choice process using a multinomial logit structure. The report states that the development of the model used "fuzzy logic" to represent the way in which passengers receive the various factors that influence their choice, although the report does not describe this further. The resulting equations are not given in the report, so it is not possible to determine how this approach differs from other models that attempt to achieve the same objective. From the information given in the report, the model was calibrated using a maximum likelihood technique based on data from two surveys of air passengers performed at the Southern California airports, supplemented with interviews of travel agents and airline personnel. However, neither the questions asked in the survey nor the survey or interview results are presented in the report.

The report discusses the input variables needed to run the model and compares the results of using the model to allocate air passengers to the existing airport system in Southern California with the distribution of passengers between Los Angeles International and Ontario International airports obtained from a recent survey (apparently not the survey used to calibrate the model). The model allocation results presented in the report appear to be in very close agreement with the survey data.

The version of the model described in this report develops separate relationships for business and non-business passengers in short-haul, medium-haul and long-haul markets. Input variables include the total number of flights at each airport, the flight frequency by destination, highway travel times to each airport from each analysis zone, air fares, highway congestion, and terminal congestion and parking characteristics at each airport. The report makes reference to incorporating the effects of alternative ground access modes, such as rail or shuttle vans, but does not provide further information. The report states that the model can generate estimates of vehicle-miles of travel, suggesting that it models ground access mode choice as well as airport choice. Many of the variables used in the model appear to be based on air passenger perceptions determined from the surveys. The applicability of such an approach to proposed future situations where survey values cannot be obtained is not clear.

The report includes a discussion of an application of the model to examine the air passenger demand that would be attracted to a number of military air bases in the Southern California region, if they were converted to civil use.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Al Chalabi, Suhail, and Saleh Mumayiz, Allocation of Enplanement Forecasts to Alternative Airports, Working Paper No. 10, Illinois-Indiana Regional Airport Site Selection Report, Appendix A, Prepared for the State of Illinois, State of Indiana and City of Chicago, TAMS Consultants, Inc., Chicago, November 1991.

The working paper describes the analytical process used to allocate air passenger demand to alternate airports as part of a study addressing the selection of a site for a future third airport to serve the Chicago region. The working paper discusses the methodology and results of air passenger surveys performed at Chicago O'Hare, Chicago Midway, and Milwaukee General Mitchell airports as well as a home interview survey of long distance travel. The report describes the distribution of base year trips for each analysis zone, divided into air trips starting from a residence, those starting from a place of employment, and those starting from a hotel or motel, as well as the approach used to forecast the future increase in trip generation rates.

The allocation of forecast trips to alternative airports was performed using a multinomial logit model calibrated on the base year trip distribution pattern by airport. The model used only two variables: travel time to each airport and the number of departing flights per week. The latter variable counted flights to all destinations, and the trip generation rates were for all trips, irrespective of destination. Since the number of weekly flights at a given airport in the base year was fixed, this term was effectively an airport-specific constant. However, it was retained as a variable, to account for changes in flight frequency in the future or the addition of new airport locations. The model was calibrated using the "ULOGIT" function of the U.S. Department of Transportation Urban Transportation Planning System software.

Ashford, Norman, and Messaoud Benchemam, "Passengers' Choice of Airport: An Application of the Multinomial Logit Model," Transportation Research Record, Number 1147, 1987.

The authors use a multinomial logit model to determine airport choice in a multi-airport region. They propose that airports don't have geographically distinct "catchment areas" but instead people choose among the available airports. The significant variables affecting the choice were assumed to be airport access time, flight frequency, and air fare. These three variables were the most frequently cited reasons given by passengers for their choice of an airport in a 1978 survey by the U.K. Civil Aviation Authority (CAA). The authors believed the variables to be independent of each other and that their importance would vary with trip purpose.

Trip purposes were classified as domestic, international business, international leisure, and international inclusive tours. The data required for each passenger were surface origin, flight destination, age, day of the week on which the trip was made, trip purpose, selected airport, travel time from surface origin to all competing airports, the number of flights from the competing airports to the destination for that day of the week, and air fare from competing airports to the selected destination.

Most of this data was obtained from the individual trip records of the 1975 and 1978 origin-destination surveys carried out by the CAA. The air fare and flight frequency for each trip were obtained from the ABC World Airways Guide.

Central England was chosen as the study area because of the availability of data in a suitable form. The origin airports that were considered in the study were the following: Manchester, Birmingham, East Midlands, Luton (for inclusive tours only), and Heathrow. The destination airports considered in the analysis were the following:

- Domestic: Belfast, Jersey, Glasgow, Aberdeen;
- International: Dublin, Amsterdam, Frankfurt, Brussels; and
- Inclusive tours: Palma, Alicante, Ibiza.

The authors noted that the property of "Independence from Irrelevant Alternatives" (IIA) allowed the introduction of new alternatives without requiring re-estimation of the model. This allowed the model to be flexible enough to handle scenarios with fewer or more airports than contained in the original formulation. The IIA property can be expressed as follows:

$$\ln(Pik / Pgk) = Vik - Vgk$$

where Pik is the probability of traveler k choosing airport i and Vik is the utility of airport i for traveler j, making the ratio (Pik / Pgk) independent of any third option.

Separate models were calibrated for the four different trip purposes. The calibration was done using a computer program written by Ben-Akiva in 1973, which is based on a maximum likelihood technique. The form of the utility function with the explanatory variables used in the model was:

$$V = a1*(\text{travel time}) + a2*(\text{flights/day}) + a3*(\text{air fare})$$

For business and inclusive tour passengers, travel time was considered to be the most important factor. This was because the absolute value of the direct elasticities of frequency was greater than that of travel time. For domestic and leisure passengers air fare was the most important factor and travel time was the second most important.

The results show that access time, air fare, and flight frequency cannot be considered as equal determinants of airport choice. The trip purpose must be considered in weighing the importance of these explanatory variables.

Ashford, Norman, "Predicting the Passengers' Choice of Airport," *Airport Forum, Vol. 19, No. 3, June 1989.*

This article discusses the use of disaggregate airport choice models to predict how air passenger demand is attracted to multiple airports in a region. It summarizes the results found in a study of airport choice in Central England described by Ashford and Benchemam (1987). It also discusses the application of a similar modeling technique in Nigeria, where it was found that only access time was a statistically significant variable in explaining airport choice and the majority of air passengers were traveling on business, so no stratification by trip purpose was possible. The article suggests that the reason that air fare and flight frequency did not appear to be factors in the choice of airport could have resulted from the regulated structure of air transportation in Nigeria, which prevented fare competition and ensured that there was no appreciable difference in flight frequency between the alternative airports in the study.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Augustinus, J. G., and S. A. Demakopoulos, "Air Passenger Distribution Model for a Multiterminal Airport System," Transportation Research Record, Number 673, 1978.

This report discusses expansions and modifications made to the Intercity Transportation Effectiveness Access/Assignment Model (ITE-AAM) developed by Peat, Marwick, Mitchell and Company under contract to the U.S. Department of Transportation in 1970. The changes to this model were made by the Port Authority of New York and New Jersey under contract to the Tri-State Regional Planning Commission.

The purpose of the modifications to the model was to reflect more realistic passenger behavior patterns. The original model contained the assumption that passengers always select the most convenient airport, as if each passenger knows the exact measure of convenience for each airport option and will always choose the best no matter how close the other options are to the best option. This "winner take all" assumption was regarded as an oversimplification of passenger behavior by the Port Authority. Therefore they modified the model to allow passengers to distribute themselves among the available facilities rather than being assigned to the theoretically most convenient airport. The Port Authority was then able to calibrate the model using their own inflight air passenger surveys. This calibration was the main focus of the report.

The convenience of an airport was measured in monetary terms and was described as the cost of using an airport. This was true for both the original model and the modified model. The cost of using an airport consisted of all costs incurred from the passenger's origin to aircraft takeoff. They include out-of-pocket costs and the value of time. The costs related to the value of time were broken down into non-volume dependent costs and costs incurred by congestion. The cost of using an airport was defined to include the cost of using the airport terminal. Therefore, walking distance and congestion at the terminal helped determine airport choice.

The modified distribution function used by the Port Authority was very similar to one developed in 1967 by the Rand Corporation for the Port Authority. The structure of the distribution function is given as follows:

$$W_{ij} = \frac{\left(\frac{CC_i}{C_{ij}}\right)^{\alpha}}{\sum_{k=1}^{P}\left(\frac{CC_i}{C_{ik}}\right)^{\alpha}}$$

where

Wij = fraction of passengers from zone i who will select airport j,

Cij = cost for passenger from zone i to use airport j (as discussed above),

CCi = cost of the cheapest airport for a passenger from zone i, and

α = an index of passenger sensitivity with respect to cost differences among airports.

The Port Authority believed this functional relationship was a logical choice because it allowed passengers to make an airport selection based on the relative convenience of an airport in a particular situation. Another important aspect of the modified model formulation was that it ensured that there would be no undistributed residual, or in other words the sum of the individual shares of passengers to each airport from a particular zone would always equal one.

Determining α was the most important part of this study. If α were to approach infinity then passengers would be extremely sensitive to the relative cost of using an airport and the modified model (given above) would act like the original model and distribute passengers on a "winner take all" basis. At the other extreme, if α were to approach zero, meaning that passengers are insensitive to the relative cost of using an airport, passengers would be distributed equally among the available airports. Since the Port Authority viewed neither of these extremes as valid assumptions, the calibration would have to determine a value of α based on the air passenger surveys.

The air passenger surveys provided information on the passengers origin, trip destination, trip purpose, and residence. However, the calibration only used the passengers' origins and destinations. The passengers' origins were used to determine the number of trips from each of the 142 origin zones, instead of using a theoretical trip generation model as in the original ITE-AA model. The passengers' destinations

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

were used to stratify the passenger market based on length of haul in order to determine differences in sensitivity to airport access convenience. There was no stratification with respect to trip purpose or residence in this study.

The method for calibrating the model (for finding the correct α value) was to try different α values and compare the model results for each value with the survey results and determine the value for α that gave the best fit. The values of 5, 10, 15, and 25 were used in the calibration process.

The results of the calibration showed that α values between 5 and 15 were the most appropriate. It was also determined from the trip distance stratification, that trips in the lower distance range were better represented by higher α values and trips in the longer distance range were better represented by lower α values. This result suggests that the cost of using an airport is less important to long-haul travelers than to short-haul travelers. It could also result from the fact that the airport with the most long-haul flights (i.e. Kennedy) had the highest intra-airport travel times.

The authors believed that some of the deviation from actual behavior could be explained by further stratifying passengers based on trip purpose (business versus personal travelers) and passengers residence (residents versus visitors). However, this step was not taken so there is no evidence from this study to confirm these assumptions.

This model is similar to the other airport choice models in that passengers distribute themselves among the available airports based on the relative convenience of alternative airports. However this model uses a cost ratio rather than a cost difference (as in the multinomial logit model) to measure the relative convenience.

By making some approximations, this model can actually be written as a multinomial logit model. Using the above notation, since CCi is the same for all j, (CCi)α cancels in the top and bottom giving

$$W_{ij} = \frac{(1/C_{ij})^{\alpha}}{\sum_{k=1}^{P}(1/C_{ik})^{\alpha}} = \frac{e^{(-\alpha^{*}\ln(C_{ij}))}}{\sum_{k=1}^{P} e^{(-\alpha^{*}\ln(C_{ik}))}}$$

Over typical values for Cik, the natural logarithm of Cik can be approximated by a linear function, giving

$$W_{ij} \approx \frac{e^{(-\beta^{*}C_{ij})}}{\sum_{k=1}^{P} e^{(-\beta^{*}C_{ik})}}$$

which is the multinomial logit model with Uik = -ß*Cik.

The main difference between this model and the other airport choice models in the review, besides the functional form, is that airport choice in this model is determined solely by access costs with no importance given to air fare or flight frequency. However, access cost in this model accounts for more than similar variables in other airport choice models because in addition to travel time and out-of-pocket costs, it includes the journey time added due to congestion at the airport terminal and walking distance in the terminal. Therefore in this model, other things being equal, terminals with a higher level of service will attract more passengers.

Basar, G., and C.R. Bhat, A Parameterized Consideration Set Model for Airport Choice: An Application to the San Francisco Bay Area, Technical Paper, Department of Civil Engineering, The University of Texas at Austin, August 2002.

Author Abstract: Airport choice is an important air travel-related decision in multiple airport regions. This paper proposes the use of a probabilistic choice set multinomial logit (PCMNL) model for airport choice that generalizes the multinomial logit model used in all earlier airport choice studies. The paper discusses the properties of the PCMNL model, and applies it to examine airport choice of business travelers residing in the San Francisco Bay Area. Substantive policy implications of the results are discussed. Overall, the results indicate that it is important to analyze the choice (consideration) set formation of travelers. Failure to recognize consideration effects of air travelers can lead to biased model parameters, misleading evaluation of the effects of policy action, and a diminished data fit.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Bondzio, Lothar, "Study of Airport Choice and Airport Access Mode Choice in Southern Germany," in Seminar K: Airport Planning Issues, Planning and Transportation Research and Computation (International) Co., 24th Annual Meeting, Brunel University, 1996.

The paper describes the development of an airport choice model that was calibrated on the results of an air passenger survey at four airports in Southern Germany: Frankfurt, Munich, Stuttgart and Nuremberg. The study tested the use of a multinomial logit structure as well as the use of a nested logit structure, with two alternative choice hierarchies, one with the airport choice at the higher level and airport ground access mode choice at the lower level and the other with the airport choice at the lower level. Separate parameters were developed for resident and non-resident travelers on business trips and for travelers on non-business trips.

It was found that the second of the two nested choice structures, with the airport choice at the lower level (i.e. air travelers first choose the airport and then their access mode), gave better results. The model considered four access modes: drive, drop-off, taxi and public transportation, with rental car used for the drive mode by non-residents. Ground access variables included travel time, cost, income and the amount of luggage, although coefficients for these variables were not presented in the paper.

Bradley, Mark A., "Behavioral Models of Airport Choice and Air Route Choice," in Juan de Dios Ortuzar, David Hensher and Sergio Jara-Diaz (eds.), Travel Behavior Research: Updating the State of Play (chapter 9), Elsevier, Amsterdam, 1998.

Author Abstract: An understanding of air passenger route choice is crucial for airport capacity planning. Development of main and regional airports, as well as changes in the road and rail transport system for airport access, will influence the relative demand for flights from competing airports. Changes in the frequency and price of flights from the various airports are also expected to result from deregulation, airline mergers and aircraft technology improvements. This chapter describes a study undertaken by Hague Consulting Group for The Netherlands Civil Aviation Authority. The purpose of the study was to collect and analyze market data to provide models of air traveller route choice. Using Stated Preference (SP) survey methods, models were created for the choice between competing departure airports and, when relevant, the choice between direct and transfer flights. These models will be used to analyze future demand for Amsterdam Schiphol airport and for regional airports in the Netherlands. The chapter contains a discussion of the issues involved in the analysis of air traveller's route choice, summarises the design and execution of a SP experiment among passengers at Amsterdam, Eindhoven and Brussels airports, describes analyses done on the survey data, including the segmentation of the passenger market based on journey purpose and destination, presents choice models estimated using the SP data and provides a discussion of the results and their usefulness in planning.

Campbell, B., Multiple Airport Demand Allocation Model, Report FAA-AVP-77-39, Federal Aviation Administration, Washington, D.C., September 1977.

This report documents the Multiple Airport Demand Allocation Model (MADAM), originally developed in 1971 by Simat, Helliesen and Eichner, Inc. The predecessor of MADAM was devised for a study of the effect of introducing jet aircraft into Washington National Airport. MADAM was developed for the Metropolitan Transportation Authority of the State of New York to assist in formulating a master plan for the development of Stewart Airport in Newburgh, New York as a potential fourth New York area air carrier airport.

The complete MADAM contains four major elements:

1. Calibration of demand model equations relating the volume of demand in previous years to variables which significantly explain the level and composition of the demand.
2. Forecast of the future demand by using the calibrated demand model, the calculated elasticities (if constant) or elasticity functions (if variable), and the independently forecast rate of change in the explanatory variables.
3. Assignment of demand to airports.
4. Scheduling of flights on a market-by-market basis for each of the alternative airports.

Because of the interaction between demand and flight frequency the model must iterate through elements 2, 3, and 4 until equilibrium is reached.

Early versions of MADAM generated the initial allocation of local passenger demand to airports in the region by the shortest door-to-door time from local zone of origin to the destination city. Under this all-or-nothing allocation, all passengers from a zone were assigned to the same airport with no consideration for the relative difference in trip times using other airports. The airport ground access portion of the total trip time was developed by assuming a uniform set of regional traffic conditions. This assumption ignores the level of service offered by different modes, varying mode availability in different zones, party size, and cost of parking.

The airport schedules are generated within MADAM once the initial allocation of originating passengers to airports is made. The model iterates to redistribute the demand between each local airport and external city to reduce overall passenger schedule waiting, defined as the difference between when a flight is scheduled and when it is desired for passengers in that market. Excess demand is redistributed from the overcapacity airports in the same way as the initial air passenger allocation to each undercapacity airport. The process continues until no airport has demand exceeding capacity.

The version of MADAM described in the report (version 6) has the capability of distributing the passengers from a zone to any of the local airports, based on an exponential formula and a theoretical utility function that takes into account the difference in access times to each airport. The curve giving the distribution is defined by empirically determining a parameter value through trial and error using MADAM. The form of the equation was not given in the documentation, but it appears from the description that it is very similar to a logit model in the same manner as the equation used in the Intercity Transportation Effectiveness Access/Assignment Model (Augustinus and Demakopoulos, 1978).

One interesting result from an early application of MADAM showed that there is a lower elasticity with respect to schedule waiting time than for other travel time. Campbell suggested that this indicated ground accessibility has a greater impact on airport choice than flight frequency.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Furuichi, Masahiko, and Frank S. Koppelman, "An Analysis of Air Travelers' Departure Airport and Destination Choice Behavior," Transportation Research, Vol. 28A, No. 3, May 1994.

Author Abstract: This paper formulates and estimates nested logit models of departure airport and destination choice for international travel. The empirical analysis was accomplished using a 1989 survey of international travelers departing from Japan. The estimation results support the use of nested logit rather than multinomial logit models. Analysis of the estimated parameters indicates that both business and pleasure travelers have high values of time for both line-haul and access time.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Halcrow Group Ltd. and Scott Wilson Kirkpatrick & Co. Ltd., Rules and Modelling: A Users Guide to SPASM, Prepared for the Department of Transport, Local Government and the Regions, South East and East of England Regional Air Services Study, London, England, January 2002.

This report provides a detailed user's guide to the SERAS Passenger Allocation System Model (SPASM) that was developed for the South East and East of England Regional Air Services (SERAS) Study undertaken by the United Kingdom (U.K.) Department of Transport, Local Government and the Regions (now the Department for Transport) to examine the demand for airports in the South East and East of England through the year 2030 and consider options for providing airport capacity to meet that demand. The principal, although not the only, focus of this study was the need for future airport capacity to serve the London area. In addition to adding runways at existing airports, including London Heathrow, the study also considered the development of entirely new airports at Cliffe in North Kent and Alconbury in Huntingdonshire.

SPASM has played a central role in this study. The model allocates air passenger demand traveling between a set of ground origin zones and foreign or domestic destinations to a set of airports in the study region. It also converts the resulting passenger volumes into the associated number of air transport (aircraft) movements at each airport. The basis of the model is a multinomial logit choice model that considers the total generalized cost of using each alternative air route for travel between a given origin and destination zone, where an air route is defined in terms of the airports serving the origin region and destination zone. The generalized cost combines the actual cost and travel time components into a single value for each route, including the costs and travel time involved in the surface access and egress segments of the trip. Separate sub-models are specified for different market segments:

- International scheduled U.K. business passengers,
- International scheduled U.K. leisure passengers,
- International scheduled foreign business passengers,
- International scheduled foreign leisure passengers,
- International U.K. charter leisure passengers, and
- Domestic scheduled passengers

Domestic scheduled passengers (those whose journeys start and end in a U.K. mainland district) are forecast in a separate stand-alone model that is integral to SPASM. Two other market segments are modeled using parameters borrowed from one of the calibrated market segments above, instead of being calibrated separately:

- Passengers connecting between international flights, and
- International passengers on low-cost carriers.

Passengers connecting between domestic and international flights are accounted for through the definition of alternative air routes available between domestic origin zones and international destination zones. A number of market segments are not modeled explicitly, but external forecasts are prepared on an annual basis and added in to the traffic generated by SPASM. These are:

- Domestic passengers on low-cost carriers,
- Passengers to and from Belfast International and Belfast City Airports,
- Flights to U.K. airports not modeled in SPASM, such as those in the Isle of Man and Scottish islands, and
- Operations by all-cargo aircraft.

SPASM groups international destinations into 48 zones. There are 21 zones in Europe representing travel to or from a specific airport, such as Amsterdam or Paris Charles de Gaulle. There are a further 14 zones in Europe representing travel to other airports in a country, such as the Netherlands or France, or region, such as Central Europe. The remainder of the world is divided into 13 zones. The United States and Canada are each divided into two zones: east and west. Africa is divided into three zones, while Central and South America is a single zone. Each of these larger zones is represented by a single airport (e.g. Rotterdam for the Netherlands or Toulouse for France).

The U.K. mainland is divided into 455 zones, of which the London area accounts for 33 zones.

Demand matrices are developed for travel between each U.K. zone and each international destination zone for each market segment. These matrices have been developed from air passenger surveys undertaken by the U.K. Civil Aviation Authority (CAA) between 1992 and 1997. Survey data was available for 22 of the 28 U.K. airports included in the model. For those airports for which survey data was not available, the passenger traffic was estimated from airline traffic reports by route, and allocated to origin zones using a gravity model. The proportion of the traffic in each of the different market segments was based on previous air passenger demand allocation modeling studies undertaken by the CAA.

The generalized cost for each route consists of four components: a surface access cost, the air fare, the flight time, and the schedule delay or waiting time due to flight frequency. For the international scheduled market segments it was found that best model calibration was obtained by omitting the air fare term, possibly because airlines tend to offer similar fares on all routes in the same market. For those market segments that retained the air fare term, air fares were calculated using a distance based relationship that was calibrated on reported data on the actual fares paid by respondents in the air passenger surveys. Similarly, flight times were calculated using a distance based relationship that was calibrated from published flight schedules. Routes involving a connecting flight included an interchange time penalty at the connecting airport. Travel times were converted to monetary values using an assumed values of time that varied by market segment and were based on values previously calibrated by the CAA and then adjusted to reflect changes in the real value of time since the previous CAA study. These values were also increased for future years in the application of the model. The values used (in 1998 U.K. pounds) varied from 6.98 for U.K. and foreign leisure passengers to 47.82 for foreign business passengers. All passengers in a given market segment were assumed to have the same value of time.

The generalized cost of the surface access component is derived from the National Airport Accessibility Model, a network based model that generates travel times and costs by road, coach and rail between the 455 U.K. zones and the 30 U.K. mainland airports modeled in SPASM. The costs and times are combined using the same values of time used for air travel times. Vehicle operating costs for road access (private vehicle) are calculated from the highway distance and an assumed vehicle operating cost per kilometer divided by an average vehicle occupancy value that differs for business and leisure trips. However, all passengers are assumed to have the same perceived vehicle operating cost. No consideration is given to parking costs, although a "shadow cost" is added to the total generalized surface access cost to reflect differences in airport tax charged at different airports. A fixed interchange penalty cost is applied for each interchange required for rail or coach access between the origin zone and the airport.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

The total generalized cost is calculated from the generalized cost for each of the three modes using the following relationship:

$$SACost(i,A,p) = -(1/\lambda) * \ln \{ \Sigma j \exp(-\lambda * SACost(i,A,p,j)) \} + ShadowA$$

where SACost(i,A,p) is the total generalized surface access cost between zone i and airport A for trip purpose p, SACost(i,A,p,j) is the generalized surface access cost of mode j, λ is a calibrated model scaling parameter, and ShadowA is the shadow cost at airport A. The first part of this expression is in fact the classic "logsum" relationship for the aggregate utility from a multinomial logit choice model, with a constant utility coefficient for each of the three modes and no mode specific constants, and implies that air passengers choose between the three modes based only on the calculated generalized cost of each mode.

The schedule delay due to flight frequency is assumed to be given by the following relationship:

$$\text{Schedule delay} = (1 - (1 - a)F) * 8 / F$$

where a is a calibrated coefficient and F is the number of daily flights. The expression

(1 – (1 – a)F) is intended to account for the fact that at low frequencies passengers will tend to adjust their travel plans to the flight schedule. No account is taken of whether these flights are offered by a single airline or multiple airlines. For routes involving a connecting flight, the schedule delay term is calculated for both segments of the journey and added together. No account appears to have been taken of the fact that airlines typically schedule connecting flights in banks, so that the schedule delay is that of the least frequent sector, not the sum of the two.

The relationship between passenger traffic on a route and the number of air transport movements (flight frequency) is expressed through so-called "Larame" graphs that express the relationship between the number of seats offered per week and the number of aircraft movements. These have been derived from a statistical analysis of the fleet composition on routes of different traffic density performed by the CAA, and reflect the tendency to use larger aircraft as the traffic density increases.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

The model calibration resulted in different coefficients for each of the market segments. For some market segments the coefficients for each of the cost components were statistically indistinguishable and a single value was used for each component.

The model balances the allocated passenger demand to the capacity of each airport through the use of a "shadow cost" that is added to the generalized cost of routes using that airport. This may be thought of as resulting from a combination of such factors as an airport tax, the ability of airlines to charge higher air fares on congested routes, or the cost of delays due to congestion. The shadow cost increases the cost of using those routes and diverts traffic to other routes (and hence other airports). Obviously, this only applies to U.K. airports. The model has no capability to consider capacity limits at non-U.K. airports. The increase in generalized cost due to shadow costs also reduces the total demand for travel through user-provided demand elasticity values. Equilibrium values for the shadow costs are obtained through an iterative solution, taking each constrained airport in turn and repeating the cycle as necessary if the solution at one airport causes an airport that was previously constrained to its capacity limits to again exceed them.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Harvey, Greig, ACCESS: Models of Airport Access and Airport Choice for the San Francisco Bay Region - Version 1.2, Report prepared for the Metropolitan Transportation Commission, Berkeley, California, December 1988.

This report describes a composite model of airport choice and ground access mode choice that uses the standard multinomial logit form but in a nested or tree structure. Harvey developed the models from surveys of air travelers in the San Francisco Bay Region conducted in 1980 and 1985 and from data on ground access and airline service at each of the three major airports in the region (San Francisco International, Metropolitan Oakland International and San Jose International).

Harvey states that the logit model represents the behavior of homogenous groups of decision-makers and, therefore, requires that homogenous groups of air travelers be defined. For this study, whether the travelers reside in the region and their trip purpose were considered important distinctions. This led to separate choice models for:

- Resident business travelers,
- Resident non-business travelers,
- Non-resident business travelers, and
- Non-resident non-business travelers.

The choice of airport depended on the quality of ground access to an airport and the frequency of flights to the travelers destination. The quality of ground access was defined as the expected utility of ground access to an airport, calculated as the natural log of the denominator of the multinomial logit model. Harvey considered this method to provide the best way to capture the overall quality of ground access to an airport and believed that it was an improvement over previous work which only considered highway access travel time.

In this study, Harvey found that the effect of flight frequency diminished as frequency rose (i.e., there is a decreasing marginal utility of flight frequency). He believed that this was caused by some negative attribute that was strongly correlated to high flight frequency, such as terminal congestion (Harvey, 1987). He used the following parabolic form of the daily flight frequency variable to account for this:

f(DF) = 18*DF - DF2

The utility function of the airport choice model contained four variables: an airport specific dummy variable, relative flight frequency (share of direct flights), the

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

function of daily flight frequency shown above, and the expected utility from the mode choice model.

Harvey found that the two models for business travelers had more explanatory power than the two models for non-business travelers. He suggested that this may be because non-business travelers don't behave as rationally as business travelers. This could be from a lack of air travel experience and a lack of information about air travel options. Another possible reason for the difference in explanatory power is that the non-business model may omit some critically important variables such as air fare (Harvey, 1987).

To estimate the parameters of the model, Harvey used the exogenous sample maximum likelihood technique. The estimation was facilitated by using a logit estimation package (MicroLOGIT) developed by Harvey in 1985. He adjusted the constants from the initial estimation by a method described by Ben-Akiva and Lerman (1985) to account for the fact that the sample fractions were different from the population fractions.

Harvey identified a number of problems that should be addressed in the future:

- The models treat airline service as an exogenous characteristic of the system and will not predict what airlines will do in response to different demands;
- The models do not include an air fare variable because the survey did not determine the fare class of each traveler;
- The models ignore connecting flights;
- Variables such as trip duration, income, party size, amount of luggage, gender, and age do not appear explicitly; and
- The effect of traveler experience on airport choice is not included.

Innes, J. D., and D.H. Doucet, "Effects of Access Distance and Level of Service on Airport Choice," Journal of Transportation Engineering, Vol. 116, No. 4, July/August 1990.

The purpose of this study was to determine how important access distance and other level of service variables are in determining airport choice. The study area was primarily a rural region in the northern half of the province of New Brunswick, Canada which had three airports.

Based on a review of airport choice literature, the authors decided from the outset to use a disaggregate choice modeling technique. A binary logit model was used because they believed it was only important to consider the choice between two alternatives.

The most important objective of the work was to determine the importance of an airport's proximity to the market in airport choice. However, this objective had to be abandoned when the coefficients of the distance variables in the model were found to be positive, indicating that the probability of choosing the farther airport increased as the distance from it increased. The authors felt it would be better to exclude the distance variable and focus on the level of service variables. They believed that the reason for the unexpected result was the unique demographic characteristics of the study area in relation to the location of the airports.

From the analysis of the level of service variables the authors determined that the most important factor for airport choice for residents of the study region was the type of aircraft operating at the airport. There were only two categories considered: jet and nonjet. Travelers were found to be willing to travel farther to use an airport where jet service was offered.

Other level of service variables were found to be important. The following variables were used in the models, listed in decreasing order of importance in determining airport choice:

- Type of aircraft (jet or nonjet),
- Difference in flying time to destination,
- Difference in direct flight service,
- Ticket type (full or discounted),
- Whether the ticket was paid for by the passenger or not, and
- Length of stay at destination.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Trip purpose was found to be insignificant in determining airport choice.

The authors suggest that there may be a problem with using the second and third variables together because they are strongly related. The difference in flying time to the destination was measured by including the total time in the air as well as the time on the ground at a connecting airport. This variable may have the same explanatory effect on airport choice as the variable that accounts for the existence of direct flight service, although the authors did not attempt to account for this correlation.

Using the available survey data, the authors tried different combinations of variables in their model to determine which ones were the most important. The number of variables varied from two to six. The combination that was the most effective in explaining airport choice in the study region included only two level of service variables. These were aircraft type (jet or nonjet) and flying time to the destination. This model predicted the actual choice, as determined from the air passenger survey, 89 percent of the time, while other models with more variables did not perform as well.

The results of this study seem to be very strongly tied to the fact that the study region was a rural area. In an urban region with many airports, the issue of jet or nonjet service would certainly not be as important as in a rural region. The study suggests that airport choice is only dominated by a few variables and that these variables depend on the demographic characteristics of the study area.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

Mandel, Benedikt N., "The Interdependency of Airport Choice and Travel Demand," in Marc Gaudry and Robert Mayes (eds.), Taking Stock of Air Liberalization (chap. 13), Kluwer Academic, Boston, Massachusetts, 1999.

This paper describes the development of an airport choice model covering several airports in West Germany. The model applies a Box-Cox transformation to a multinomial logit model (Box-Cox Logit model). Variables in the model specification include travel cost, travel time, flight frequency, the existence of non-stop flights, the distance to the airport, and the access/egress utility from an airport ground access mode choice model. The model was calibrated using air passenger survey data from several German airports. Separate models were calibrated for business trips, personal trips (called "private" trips in the paper), and vacation trips. However, details of the ground access mode choice model or the resulting model coefficients are not given in the paper.

Monteiro, Ana B., and Mark Hansen, "Improvements to Airport Ground Access and the Behavior of a Multiple Airport System: BART Extension to San Francisco International Airport," Transportation Research Record, Number 1562, November 1996.

Author Abstract: Metropolitan regions with more than one major airport – multiple airport systems (MASs) – are important in the U.S. air transport system because of the large number of passengers they serve. Airport ground access factors strongly influence the allocation of traffic in MASs. The effect of improvements to airport ground access (by nonautomobile modes) on airport use in a MAS are analyzed. A case study of an extension of a Bay Area Rapid Transit rail link into the San Francisco International Airport (SFO) is presented. Two airport choice models were developed. One is a nested logit model in which the airport choice decision occurs at the higher level and the mode choice decision at the lower level, and the other is a multinomial logit model. The results indicated that improvements to SFO ground access would modestly strengthen SFO as the dominant airport in the San Francisco Bay Area and that most of the diversion of passengers would be from Oakland Airport.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Pels, Eric, Peter Nijkamp and Piet Rietveld, "Access to and Competition between Airports: A Case Study for the San Francisco Bay Area," *Transportation Research,* *Vol. 37A, No. 1, January 2003.*

Author Abstract: In this paper (nested) logit models that describe the combined access mode-airport-choice are estimated. A three level nexted logit model is rejected. A two level nested logit model with the airport choice at the lower level is preferred. From the estimation results, it is concluded that business travelers have a higher value of time than leisure travelers. In the (conditional) access mode choice, leisure travelers have a higher access cost elasticity (in absolute Value), while business travelers have a higher time elasticity (in absolute value). In general, access time is of large importance in the competition between airports in a region.

Samis, Robert, <u>Multiple Airport Demand Allocation Model (MADAM) Calibration and Sensitivity Analysis</u>, National Capital Region Transportation Planning Board, Metropolitan Washington Council of Governments, August 1985.

This report documents the calibration of the Multiple Airport Demand Allocation Model, as described by Campbell (1977), to study airport choice in the Washington, D.C., region. The study varied the model parameter to obtain the best fit with the airport choice pattern determined from a regional air passenger survey performed by the Metropolitan Washington Council of Governments.

Samis found that the higher the value of the parameter, the higher the proportion of passengers choosing the closest airport, other things being equal. A high parameter value, therefore would support the assumption of all-or-nothing assignment as used in early versions of the model. However, he found through trial and error that the best parameter value was not high, supporting the more flexible assumption used in Version 6 of the model. The model was also found to be insensitive to the parameter value once it was in the appropriate range.

Southern California Association of Governments, Air Passenger Demand Allocation to Military Air Bases, Los Angeles, California, April 1993.

This report describes the use of the Regional Air Passenger Demand Allocation Model (RADAM) to assess the number of Southern California air passengers that would be attracted to commercial air services at various military air bases in the region if they were converted to civil use. The report discusses the development and evaluation of RADAM, and describes the inputs required by the model. It discusses the results of applying the model to six scenarios involving the existing airport system supplemented by various combinations of three air bases: Norton Air Force Base (AFB), March AFB and El Toro Marine Corps Air Station.

The report discusses the mix of short-haul and long-haul air service assumed at each of the air bases, although the specific markets that it was assumed would be served are not given. Air fares and parking costs at the converted air bases were assumed to equal current values at nearby existing airports (Ontario International and John Wayne Orange County). Congestion factors at each airport in the system, including the existing airports, were adjusted iteratively to reflect the reallocation of demand between airports.

The results of the allocation show that neither March nor Norton attracts significant volumes of traffic under any of the scenarios examined. If only Norton is added to the system, it is predicted to attract a little over one million passengers per year, most of whom are drawn almost equally from Los Angeles International and Ontario International airports. Adding only El Toro to the system attracts between 4 and 5 million passengers per year, depending on the air service assumptions. Somewhat surprisingly, very few of these were drawn from John Wayne Airport, in spite of the fact that air service and airport conditions at El Toro were assumed almost identical to those at John Wayne.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Southern California Association of Governments, RADAM Airport Demand Allocation Model – Basic Description, A Discussion Paper for the SCAG Aviation Task Force RADAM Model Workshop, Los Angeles, California, October 17, 2002.

This paper provides an overview of the Regional Airport Demand Allocation Model (RADAM) that was developed for the Southern California Association of Governments. The paper provides a general description of the structure of the model and discusses the analysis zone system used, the need to reflect air passenger perceptions and behavior, and a modeling approach that is described as "asymmetric logic". However, the paper does not provide more information on "asymmetric logic", and no details are provided on the functional form of the model or the values of the model coefficients. The variables used in the demand generation equations are listed, but no details are provided on how they are included in the model. Similarly, the paper lists a large number of variables that are stated as being used in the airport choice component of the model, but no details are provided on how they are defined, how they are included in the model, or their estimated coefficients. The paper mentions several special features of the model, including a high-speed rail module, the ability to calculate ground access emissions, the ability to calculate airport employment generation and distribution, and an air cargo model that has been integrated with the air passenger model. However, no further details are provided on the structure or operation of any of these features.

Windle, Robert, and Martin Dresner, "Airport Choice in Multi-Airport Regions," Journal of Transportation Engineering, Vol. 124, No. 4, July/August 1995.

Author Abstract: A logistic model is constructed to predict airport choice in a multiple-airport region and estimated using passenger data from the Washington, D.C./Baltimore area. In agreement with previous work, it was found that airport access time and flight frequencies were significant predictors of airport choice, although, as might be expected, decreased access time and additional flight frequencies were more important to the business traveler than to the nonbusiness traveler. Additional estimations indicated that when only those passengers within reasonable proximity of more than one airport were included in the estimation, the significance of access time decreased and that of flight frequencies increased. Additional variables for a passenger's experience with an airport were then included in the model and were significant. This would indicate than passengers who have used an airport will tend to continue to use the same airport, all other factors being equal.

APPENDIX B

ANNOTATED BIBLIOGRAPHY

AIRPORT GROUND ACCESS MODE CHOICE MODELS

Chebli, Hussein, and Hani S. Mahmassani, <u>*Air Travelers' Stated Preferences Towards New Airport Landside Access Mode Services*</u>*, Paper presented at the Transportation Research Board Annual Meeting, Washington, D.C., January 2003*.

Author Abstract: Understanding air passenger access mode choice and willingness to adopt new services could help in designing and marketing new services, as well as planning airport infrastructure improvements. The objective of the study is to uncover the factors that affect air travelers' willingness to adopt new services that could help reduce ground access congestion around airports. A stated preference web-based survey was conducted for this purpose, with travelers from Dallas Fort-Worth, Houston and Austin. The focus is on modeling a particular aspect of air travelers' behavior: stated willingness to adopt new access services (transit, rail, and off-airport terminals). Stated intentions in response to new services were analyzed using ordered probit models designed to measure the underlying propensity to use these services. Insights from the stated preference models gave an indication of the type of passenger that is likely to use the various services. A factor analysis helped in classifying travelers into three different categories namely, energy conscious travelers, sociable travelers, and those who have a need for independence and control.

Ellis, R.H., J.C. Bennett, and P.R. Rassam, "Approaches For Improving Airport Access," Transportation Engineering Journal, Vol. 100, No. TE3, August 1974.

The paper presents one of the first airport ground access applications of a multinomial logit mode split model, termed by the authors an "n-dimensional logit model". The model was calibrated by differentiating between business and nonbusiness trips as well as between trips to and from the airport. The data set used was the Washington-Baltimore Airport Access Survey published in 1966. The survey did not distinguish between residents and non-residents of the region.

The ground access modes considered in this model were private car, rental car, taxi and limousine. Only two variables, cost and time, were used for each mode, as well as a mode specific constant. For each mode and trip purpose classification, travelers going to the airport were found to be more willing to change modes. The authors believed this could be a result of the travelers' desire to catch their flights.

The authors note that improvements in air service have not been matched by improvements in ground transport service to airports. Because of highway congestion, automobile access now takes longer and there is "reduced arrival time reliability". This causes travelers to allow more time to reach the airport than they actually need in order to be certain of catching their flight. Therefore, according to the authors, terminal waiting time will increase more rapidly than overall air travel demand.

The authors suggest some ways for improving airport ground access. One possibility would be to create "priority access routes for public transportation". These routes could be lanes used exclusively by public transportation. Another possibility would be to use satellite terminals at regional shopping centers. Travelers could drive to a local shopping area, park, and be transported to the airport. No mode is specified by the authors but, from the context, it could be bus, taxi, or limousine. In terms of off-site passenger processing, the authors believe that its only justification would be to transport people by reliable, exclusive right-of-way access systems directly to the planeside. If free parking were provided at off-site facilities, people would be diverted to them to avoid high airport parking costs. Another possibility suggested by the authors for improving airport access would be to extend regional rapid transit systems to airports.

Gosling, Geoffrey D., An Airport Ground Access Mode Choice Model, Technical Document UCB-ITS-TD-84-6, Institute of Transportation Studies, University of California, Berkeley, July 1984.

The mode choice model described in this report was based on a study of airport ground access in the North Bay region of the San Francisco Bay Area. Its core is a multi-mode, multinomial logit model. The data needed to calibrate this model was obtained from a 1980 air passenger survey performed by the Metropolitan Transportation Commission.

Separate models were calibrated for resident and non-resident air travelers. Residents of the region were assumed to have the choice of four modes:

- Automobile parked for duration of trip,
- Dropped off at airport by automobile,
- Local airporter service (scheduled airport bus) serving Marin and Sonoma Counties, and
- Airporter service from San Francisco.

Non-residents were also assumed to have a choice of four modes, except that parking an automobile at the airport was replaced by a composite rental car and taxi mode.

The general form of the utility function used in this model was as follows:

$$Vi = a1 + a2*ACT + a3*WT + a4*LHT + a5*(C/PCI)$$

where the a's are parameters and

ACT	=	access time to fixed route modes (minutes),
WT	=	waiting time for scheduled modes (minutes),
LHT	=	line-haul time for fixed route modes, or driving time for automobile modes (minutes),
C	=	out-of-pocket costs (dollars), and
PCI	=	per capita household income (thousand dollars).

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

The parameters were estimated using TROMP, a program developed at the Institute of Transportation Studies to calibrate logit and probit models using the maximum likelihood estimation technique. The following are some aspects of the model:

- The varying value of time to air parties with different incomes was accounted for by expressing out-of-pocket cost in terms of the per capita household income. The first two members of a household were given full weight and other members (assumed to be children) were weighted one half.
- The influence of air party size was recognized by expressing total cost and other components independent of party size as a cost (or time) per party member.
- The automobile operating cost was determined by expressing the cost in terms of minutes of travel time rather than a cost per mile. This helped capture the difference between actual and perceived costs.
- Trip purpose was not included (business and non-business trips were not differentiated).
- It was found from the calibration that the value of the time of the driver dropping an air party off at the airport was about half that of the air passengers.
- A dummy variable was included in the utility function for non-resident drop-off trips that was zero if the trips originated from the home of a friend or relative, or a large negative value otherwise. This accounted for the fact that non-residents staying in a hotel usually do not have the option of being dropped off at the airport.

The original model was reformulated to include the possibility of a Bay Area Rapid Transit (BART) extension to the San Francisco International Airport (SFO) and to include the use of taxis for access to fixed route modes. Since a BART station does not exist at SFO, the egress portion of the access trip had to be estimated. It was assumed that there is a disutility associated with carrying bags, especially on crowded trains. Thus peak period travel was penalized by adding a dummy variable.

Two different types of data were needed in this model. For the alternative transportation modes, the following data were required for each origin zone:

- Driving time to the airport,
- Local airporter service access, line-haul and waiting time,
- Access time to SF Airporter,

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

- Access, line-haul and waiting time for BART,
- Distance to the airport,
- Bridge tolls,
- Local airport bus and BART fares, and
- Taxi flag-drop and meter rate per mile.

The following data was required for each air party:

- Air party size,
- Household income and size,
- Trip duration,
- Resident or visitor,
- Type of trip origin, and
- Zone of trip origin.

Gosling suggested the model could be improved to better handle peak and off-peak travel conditions, and the effect of baggage on the use of BART, by taking explicit account of the time of departure and number of bags, as well as recalibrating the model for different trip purposes.

Halcrow Group Ltd., SERAS Surface Access Modelling, Prepared for the Department of Transport, Local Government and the Regions, South East and East of England Regional Air Services Study, London, England, July 2002.

This document describes the structure and validation of the surface access models used in the South East and East of En gland Regional Air Service (SERAS) study undertaken for the United Kingdom Department of Transport, Local Government and the Regions. It contains four sections that describe:

- Employee trip distribution model
- Air passenger mode choice model development and validation
- Highway model validation
- Public transport assignment model validation

The structure of the passenger mode choice model is stated to be the same as the Heathrow Surface Access Model (HSAM) developed by the MVA Consultancy for the British Airports Authority. This is a multinomial logit model that covers 11 ground access modes and has separate coefficients for six market segments:

- U.K. business passengers on domestic trips
- U.K. business passengers on international trips
- U.K. leisure passengers on domestic trips
- U.K. leisure passengers on international trips
- Non-U.K. passengers on business trips
- Non-U.K. passengers on leisure trips

The model uses a generalized cost approach that considers the travel time and out of pocket costs (fares and parking), as well as cost penalties for interchanges on public modes.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

Harvey, Greig, ACCESS: Models of Airport Access and Airport Choice for the San Francisco Bay Region - Version 1.2, Report prepared for the Metropolitan Transportation Commission, Berkeley, California, December 1988.

This report describes a composite model of airport choice and ground access mode choice based on a study of air passenger behavior at the three major airports in the San Francisco Bay Area. The ground access mode choice submodel is used as part of the airport choice model, as described in Appendix A.

Harvey used three levels of modal complexity in his ground access mode choice models by embedding the models in a hierarchical framework. The assumption of a hierarchical framework was tested by comparing the quality of its results against the results of a fully simultaneous model where all modes are considered on the same level. The hierarchical structure produced much better results.

Harvey recognized five basic types of airport access service, which he termed level one modes. These were drive, drop-off, transit, airporter and on-call. Nine level two modes subdivided auto drive into rental car and drive and park, transit into public bus and rail, and on-call into limousine, taxi and shared-ride van. The level three modes distinguished the parking used, whether parked vehicles also used the terminal curb, and the access mode to rail and airporter.

The variables Harvey used for specifying the model were automobile in-vehicle travel time, bus in-vehicle time, rail in-vehicle time, walk distance, moving walkway distance, wait time, travel cost, schedule mismatch time (extra time required when airporter schedules do not match flight schedules), drop-off passenger time (the round trip in-vehicle time of one non-air traveler), luggage (a dummy variable included in the transit utility when the number of luggage pieces per party member was greater than one), household size, departure from home (a dummy variable which takes the value one if the traveler leaves from their own home or the home of a friend or relative), and the gender of the traveler (a dummy variable in the drop-off and on-call utilities that takes the value one if the traveler is a woman).

Harvey found that both time and cost had strong effects on access mode choice but that they were not equally important for all classifications of air passengers. Time was more important to the business traveler, while cost was more important to the non-business traveler. Other significant variables were also found not to be equally important for all air passenger classifications. For example, the amount of luggage, gender of the traveler, and income were much more important in the non-business model than in the business model.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

The distinction between residents and non-residents was found to be less obvious than the distinction between business and non-business travelers. In comparing the coefficients for the time and cost variables in the resident and non-resident models there is little difference. The same is true for non-business models. Harvey found that the explanatory power of the resident model was superior to the non-resident model. He believed that this was caused by the residents greater knowledge of the available ground access options.

He suggested the following potential improvements:

- Expand the range of air traveler characteristics. (e.g., distinguish between vacationers and those visiting friends and relatives.)
- Explore non-linearities in the independent variables. He noted that he found strong evidence of diminishing marginal disutility of time.
- Search for links between anticipated flight conditions and mode choice behavior (e.g., longer flights may correlate with greater disutility of access time).

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

Howard Humphreys and Partners, Heathrow Surface Access Study, Report prepared for the U.K. Department of Transport, Leatherhead, Surrey, England, June 1987.

In this study, nested (or hierarchical) logit models were used to evaluate ground access services to London Heathrow Airport, although the model was originally developed to evaluate rail services to London Stansted Airport.

Separate mode share models were developed for four different air passenger segments: UK leisure, Non-UK leisure, UK business and Non-UK business. Seven different modes were considered: British Rail, Underground, bus, taxi, coach, park and fly, and kiss and fly. The data for the models were taken from air passenger surveys administered in 1984 at both Heathrow and Gatwick Airports by the Civil Aviation Authority. A stated preference survey of air passengers was also administered at Heathrow Airport to supplement the 1984 surveys.

The nested structure simulated decisions being made at different levels. For example, at the highest level there may be the choice between public and private transport, next a choice between public transport modes, and on the lowest, a choice between rail modes.

In the original model there was no choice between rail modes. There was a single rail mode which could be either British Rail or Underground. For forecasting the use of rail to Heathrow, the original model was extended to incorporate competition between British Rail and Underground services. The introduction of British Rail services to Heathrow was considered the same as introducing a new mode in this study. To incorporate competition between the rail modes in the extended model an additional level was included in the hierarchical structure for each air passenger classification.

The utility function in the logit model was based on a generalized cost (GC), measured in minutes:

$$Ui = -p*GCi$$

where p is the model parameter. The authors point out that the model parameter p decreases at each higher level in the hierarchy, as it should. The form of the generalized cost function for mode j is given by:

$$GCj = Mj + Tj + (Cj / r) + w*Hj + n1*I1j + n2*I2j$$

where:

Mj	=	alternative specific constant for mode j,
Tj	=	travel time on mode j,
Cj	=	travel cost for mode j,
Hj	=	headway of mode j,
I1j	=	number of major interchanges on mode j,
I2j	=	number of cross-platform interchanges on mode j,
r	=	behavioral value of time,
w	=	weight on headway, and
n1,n2	=	weights on the major and cross-platform interchanges, relative to journey time.

The model was applied incrementally so that it was only used to forecast the changes in mode shares from existing patterns given a transportation improvement. The authors believed the "incremental approach" was important because even though the overall modal shares are correctly reproduced in the model, the estimates of the effect of changes may be less reliable.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Leake, G.R., and J.R. Underwood, "An Inter-City Terminal Access Modal Choice Model," Transportation Planning and Technology, Vol. 4, No. 1, September 1977.

The model developed in this study focused on the choice of access/egress mode to airports and passenger railroad terminals. It was developed as part of a larger modeling effort to determine important factors in the choice of mode for inter-city travel. The access/egress models developed in this study were for the Glasgow, Liverpool, London, and Manchester regions. The data used to calibrate the models was obtained from a survey of rail and air passengers on inter-city routes within Great Britain, commissioned by the Department of Trade and Industry. Survey questionnaires for rail passengers were returned by mail, while questionnaires for air travelers were collected by airline cabin staff just before landing.

The model structure used to calculate the mode choice probabilities was of the multinomial logit (MNL) form. The only two modes considered in this study were car and public transport. Public transport was not broken down into separate modes because for airports there were small sample sizes and for rail terminals one particular mode tended to dominate. Therefore, the model only used a binary choice equation:

$$\ln\left(\frac{P_{ijp}}{P_{ijc}}\right) = \alpha + \beta * (G_{ijc} - G_{ijp})$$

where

Pijp, Pijc	are the probabilities of a traveler from zone i to terminal j choosing public transport or car, respectively
Gijp, Gijc	are the generalized costs of travel from i to j by public transport and car, and
α and β	re calibration constants.

The constant α was added to the equation to account for the access/egress mode choice influences not captured in the generalized cost functions. The model was calibrated by least-squares regression procedures.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

The following factors were considered by the authors to have a major influence on access/egress mode choice:

- Relative in-vehicle travel time,
- Relative excess travel time,
- Relative money costs,
- Car availability,
- Public transport availability,
- Access/egress distance,
- Origin or destination location,
- Household income, and
- Preferences and comfort.

The appropriate data were not contained in the survey to allow the use of all of these factors. Therefore, the following information was used in the analysis:

- Relative access/egress travel times,
- Relative money costs,
- Car ownership,
- Household income,
- Geographical location of origin or destination, and
- Trip purpose.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Using this information from the surveys, the following generalized cost functions were adopted in the model:

$$Gijp = mijp + v*tijp$$

$$Gijc = mijc + v*tijc$$

where

mijp, mijc	=	money cost of travel from i to j by public transport and car,
tijp, tijc	=	rip time between i and j by public transport and car, and
v	=	value of time for a traveler.

The value of travel time was assumed to be proportional to household income, given by:

$$v = k*I$$

where

I	=	household income (in the same units as v), and
k	=	a constant.

Separate models were calibrated for work and non-work trips, car owners and non-car owners, rail and air passengers, and each city region. These distinctions were decided upon when preliminary investigations yielded statistically significant differences for modal splits between these groups.

The authors originally tried to calibrate the model using modal splits by geographical zones but this was unsuccessful. The model was then calibrated by grouping travelers together with similar values of generalized cost difference (Gijc - Gijp) and using a least-squares regression analysis.

The estimated k values are high compared to other intra-urban analyses. The reason for this is that no distinction is made between in-vehicle time and excess time, which are not valued the same by travelers. In the calculation of generalized cost, there is no distinction between these times, and therefore the typically higher value of excess

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

time increases the value of k. Significant differences in k values were observed for the two different trip purposes, with work trips having a consistently higher k value.

Positive values of α were considered to be a measure of bias towards public transport and negative values a measure of bias toward car travel. The values of α for those not owning cars was always greater than for car owners. α was also always greater for travel to and from rail stations than airports, which indicates a bias towards the use of car for air travelers. Significant differences in α were also found between different regions.

The parameter β indicates the sensitivity to the differences in generalized cost between the two modes. The values of β were similar for car owners and non-owners. The values of travel to and from rail stations, however, were often higher than those for airports. This indicates that rail travelers are more affected by changes in cost or time than are air travelers. The relative insensitivity of the use of public transport by air travelers to the total cost difference, compared to that for rail travelers suggests that there are other significant factors involved in mode choice by air travelers which are not captured in the generalized cost function. One factor may be the security derived from using a familiar mode and the ensuing better ability to determine the travel times involved. More predictable arrival time may be relatively more important than actual travel time for air travelers, because of the lower frequency of departures typical for air travel and therefore the greater impact of missing a flight.

Lythgoe, W.F., and M. Wardman, "Demand for Rail Travel to and from Airports," Transportation, Vol. 29, No. 2, May 2002.

Author Abstract: Rail access to airports is becoming increasingly important for both train operators and the airports themselves. This paper reports analysis of inter-urban rail demand to and from Manchester and Stansted Airports and the sensitivity of this market segment to growth in air traffic and the cost and service quality of rail services. The estimated demand parameters vary in an expected manner between outward and inward air travellers as well as between airport users and general rail travellers. These parameters can be entered into the demand forecasting framework widely used in the rail industry in Great Britain to provide an appropriate means of forecasting for this otherwise neglected market segment. The novel features of this research, at least in the British context, are that it provides the first detailed analysis of aggregate rail flows to and from airports, it has disaggregated the traditional generalised time measure of rail service quality in order to estimate separate elasticities to journey time, service headway and interchange, and it has successfully explored departures from the conventional constant elasticity position.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

Psaraki, Voula, and Costas Abacoumkin, "Access Mode Choice for Relocated Airports: The New Athens International Airport," Journal of Air Transport Management, Vol. 8, 2002.

Author Abstract: To estimate the capacity requirements for all access related facilities of a new airport and to set pricing or operational policies it is necessary to forecast the share of each transport mode that airport passengers use. The development of these forecasts cannot be based on mere transfer of experience from other airports, particularly in the modern era of wide regulatory reforms, liberalization of the aviation market and increasing airport competition. First access modal split at the existing airport is determined via passenger classification and discrete choice modeling. Both are conducted via a passenger survey study specifically designed for this purpose. The resulting models are then employed to forecast access modal splits for the relocated airport by proper adjustment of the attribute values. The method is applied to the new Athens International Airport.

Sobieniak, J., R. Westin, T. Rosapep, and T. Shin, "Choice of Access Mode to Intercity Terminals," Transportation Research Record, Number 728, 1979.

The focus of this paper is on ground access to inter-city terminals in the National Capital Region of Canada (Ottawa-Hull and vicinity). The study looked at airports, railroad stations and bus terminals. Five access modes were considered: auto driver, auto passenger, taxi, limousine, and public transit. Separate disaggregate demand models, of the multinomial logit form, were developed for each of the three terminal types, and each model considered personal and business trip purposes. The data used to develop and calibrate these models were based on travel surveys of departing passengers in April and May of 1978 at the airport, railroad station, and inter-city bus terminals of the National Capital Region.

The airport ground access mode choice models did not include any time variables because there was very little existing transit service to the airports. Only 0.1 percent of the survey respondents used public transit to access the airport, so the transit mode was dropped from the calibration data set. The only level of service variable used in the model was trip cost. The cost coefficient for personal travelers was found to be smaller than for business travelers. No baggage variable was included because of the absence of the transit mode. Baggage was not considered to influence mode choice among the other four modes. Residence of the region, trip origin, and gender were all considered to be important determinants of mode choice.

Some interesting results from the study are that access mode choice was found to be independent of income, while intercity mode choice was found to vary with income. The authors initially believed from the first analysis of the survey data that travelers from higher income households were more likely to use single occupant automobiles or taxis for their ground access trips. However, once the models were stratified by terminal (rail, bus, or airport) and trip purpose (business or personal), there was no identifiable effect of household income. The paper states that "experiments were made treating household income interactively with the time and cost variables, as a dummy variable classification, and as an imputed wage rate." Because of their inability to find consistent results, the authors determined that household income determines the choice of intercity mode and trip purpose but is not important in determining the access mode.

As with income, the number of cars per driver in the household was found to have insignificant explanatory power. The authors originally believed that it would be an important variable because it might capture the effects of family competition for an automobile.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Spear, Bruce D., An Analysis of the Demand for Airport Bus Services at Washington National and Dulles International Airports, Report DOT-TSC-FAA-84-2, U.S. Department of Transportation, Transportation Systems Center, Cambridge, Massachusetts, May 1984.

In this study, air travelers were assumed to choose their mode of access after they selected which airport to use. This allowed the modeling of ground access mode choice without having to model airport choice. This assumption was considered acceptable by Spear because less than 2 percent of survey respondents listed "better public ground transportation" as a primary reason for choosing one airport over another.

Ground access mode choice was modeled using a disaggregate multinomial logit model calibrated using the maximum likelihood estimation technique. This technique searches for coefficient values "that generate probabilities which are most likely to produce the desired distribution of choices for the calibration data set." The computer program TROLL was used to do this and its output included values for each coefficient, the constant, and statistical measures to show how the calibrated model fits the observed data.

The calibration data set was obtained from the 1981-82 Washington-Baltimore regional air passenger survey. However, the survey lacked important information.

1. There were no observations of deplaning or transferring passengers, or of passengers boarding international flights. This eased the survey process, but biased the survey against persons who are more likely to use the airport bus.
2. There was no information on the air passenger's awareness of airport bus services, which prevented an analysis of how better marketing would affect ridership.
3. There was no information on auto availability or duration of air travel from the survey respondents. These two attributes exhibit a strong correlation with the choice of access mode. Longer air trips discourage travelers from parking their cars at the airport. Without auto availability data, one cannot distinguish between those who have access to an automobile and yet choose another mode, and those with no access to an automobile who must choose another mode.

The modes that were chosen for analysis were airport bus, taxi, auto driver, auto passenger, and Metrorail (only for the National Airport model). Other modes were contained in the survey data, but were not used enough to justify their inclusion in the models.

Four different sets of coefficients were developed in the final analysis for resident and nonresident models at Dulles and National airports. They contain different variables and coefficients because the types of service available for the two airports are different. For example, only National Airport is served by the Metrorail system. The following level of service variables and traveler characteristics were determined to be important:

- Excess travel time other than zone-to-zone travel time, including walk-and-wait, auto access to transit, transfer and intra-zonal times,
- Out-of-pocket cost of an access trip,
- Bus headway,
- Trip purpose, and
- Trip duration.

The last three variables were expressed as dummy variables that assumed the value 1 if the bus ran at least once per hour, the trip was for business, or the traveler's stay was for one day or less.

Other level of service variables and traveler characteristics were considered but were eliminated for various reasons. Zone-to-zone travel times were omitted because the calibrated coefficients were statistically insignificant and the signs of the coefficients were sometimes counterintuitive. Income was not included because it was statistically insignificant and difficult to forecast at the zonal level. The travel cost coefficients were found to be statistically insignificant and small in magnitude for all of the models. The signs, however, were intuitively correct for some models, and therefore travel cost was included in those models. The most important level of service variables were found to be excess travel time and bus headway.

The author's evaluation of the models was that they were "relatively weak in their ability to explain the access mode choice behavior of air passengers". The models over-assigned trips to the more frequently used access modes and under-assigned trips to the less frequently used modes. The author states that this problem is characteristic of most models calibrated using maximum likelihood estimation techniques.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Finding travel cost to be an insignificant variable in a ground access mode choice shows a serious problem with the model. If travel cost were indeed insignificant, then people would always take a taxi (or chartered limousine) to the airport. This problem casts doubts on other conclusions presented in the paper.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

Tambi, John E., and John Falcocchio, Implications of Parking Policy for Airport Access Mode Choice, Paper presented at the 70th Annual Meeting of the Transportation Research Board, Washington, D.C., January 1991.

This paper describes the use of multinomial logit models to analyze air passenger ground access mode choice with special focus on airport parking, so as to develop "rational and effective airport parking management strategies . . . consistent with air travelers' parking and airport mode choice decisions." The study focused on ground access at Newark International Airport. Data from the Port Authority of New York and New Jersey 1984/85 in-flight survey were used to calibrate the model. Four separate models were calibrated based on residence in the region and trip purpose. The four classifications were New York business, New York non-business, New Jersey business, and New Jersey non-business travelers.

The authors indicate in the abstract of the paper that air travelers prefer to park at short term lots close to the terminal area rather than long term lots, regardless of their parking duration. They state that policies need to be identified which would reduce the use of the automobile for airport access or shift parking from short term to remote lots. However, later in the paper they state that "98 percent of air travelers who park at the airport for one day or more use either the daily or remote lots." This indicates that parking duration does strongly influence parking lot choice, although, it does not provide any information on how passengers who park for longer durations might choose between the daily and remote lots.

The paper defines the following airport access modes:

1. Auto drop-off (no parking),
2. Auto park short-term (hourly lot),
3. Auto park long-term (daily lot),
4. Auto park long-term (remote lot),
5. Taxi,
6. Limousine, and
7. Bus.

The variables included in the models were travel time, travel cost (parking cost, auto operating costs, out-of-pocket costs) and a dummy variable for each mode other than drop-off.

Out-of-pocket costs, auto operating costs, and parking fees were divided by the number of air travelers in the air party. The travel time was defined as the total air passenger time from the start of the airport access trip to the airport terminal. This included vehicle access time, in-vehicle time, and terminal access time. The travel time reported in the survey was found to be a stronger explanatory variable in the access mode choice decision than the measured travel time. According to the authors, this highlights the importance of using perceived travel time rather than actual travel time as a variable in such models.

The computer software package Statistical Software Tools was used to calibrate the models using the maximum likelihood estimation technique.

The results of the study showed that the parking location choice (hourly, daily, or remote) was more sensitive to the terminal access time than the parking rate. Users of the hourly lot were highly insensitive to price regardless of trip purpose or origin. It was also found that the rates for all lots would have to be increased by more than 50 percent to cause significant modal shifts.

Satellite terminals were considered in this study as one means of reducing parking and traffic congestion at the main terminal. In order to determine how effective they might be, the authors assumed that there were three large satellite terminals in New Jersey located about 20 to 30 miles from the airport. No satellite terminal locations were considered in New York because the authors believed that the mode use and market characteristics in New York were not compatible with the concept.

Since the ground access trip from the satellite terminal to the main terminal is very similar to ground access by the limousine mode, the satellite terminal was not considered an independent alternative. The satellite terminal, therefore, replaced the limousine mode in the model. By studying various operating scenarios the authors determined that satellite terminals with non-stop service and on-airport priority treatment could remove some cars from the airport. Satellite terminals with stops enroute attracted about the same ridership as the limousine mode, indicating that the services were perceived as being the same.

The authors made the following suggestions for improving the model:

- Recalibrate the model with more recent in-flight survey data. The 1984/85 survey had some biases due to the dominating presence at Newark of People Express with its low fares.
- Estimate additional models for non-resident air travelers, and
- Include additional variables such as baggage and the frequency of flights.

APPENDIX C

ANNOTATED BIBLIOGRAPHY

AIR PASSENGER TRIP GENERATION MODELS

Keefer, Louis E., Urban Travel Patterns for Airports, Shopping Centers, and Industrial Plants, National Cooperative Highway Research Program Report 24, Highway Research Board, Washington, D.C., 1966.

Chapter 2 of this National Cooperative Highway Research Program report presents a range of information on ground access and egress trip characteristics at a number of large U.S. airports, including mode split and trip generation for air passengers, airport employees, and others. These data appear to have been synthesized from airport surveys, traffic counts and household interview surveys during the late 1950s and early 1960s. As such, they may be of questionable validity today.

Data is presented for the number of annual air passenger trips originating in a large number of metropolitan regions per 100,000 population, as well as more detailed trip generation rates by type of trip for selected airports. An analysis of the change in trip generation rates with distance from the airport for a limited sample of airports suggests that these rates declined quite steeply with increasing distance from the airport. However, some caution appears to be warranted in interpreting these data, which were based on home interview surveys and did not distinguish between air travelers and trips by other household members to pick up or drop off air travelers. It should be no surprise that those who live closer to the airport would be more likely to make such pick-up or drop-off trips.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

Keller, Charles R., Commercial Air Travel in West Virginia: Trip Generation and Attraction, Master of Science Thesis, West Virginia University, Morgantown, West Virginia, 1966.

Author Abstract: The basic objective of this research project was to explain the details of a commercial air travel survey conducted by West Virginia University during 1966 in conjunction with a National Aeronautics and Space Administration grant. The details associated with the survey are discussed and particular emphasis is placed upon the air traveler's actual trip origin and destination.

The survey represented an original attempt to ascertain each air traveler's actual point of ground origin and destination rather than the airport of origin and destination. This type of data is virtually nonexistent except for a limited study conducted in 1961 at the Washington National Airport, but it was found that this type of survey can yield reliable origin and destination data. It was also determined that an in-flight type of commercial air passenger survey is more effective than a ticket counter type of boarding passenger survey.

The survey made it possible to better understand the annual distribution of commercial air trips generated from West Virginia and neighboring areas. It was found that for all West Virginia airports, except Martinsburg, 13.1% of all outbound air passengers were destined for other areas in West Virginia, 26.8% were destined for the neighboring 100 mile region, 16.2% for the region between 100 and 200 miles outside West Virginia, and 43.9% for regions beyond 200 miles.

These 1966 data were compared to 1959-1964 Civil Aeronautics Board O-D data which showed the same respective percentages to be 14.2%, 27.5%, 18.6% and 39.8%. It was concluded, after various comparisons for each West Virginia airport city that the CAB O-D data and the 1966 survey data closely compare in the distribution of commercial air trips for the four selected sectors.

The 1966 survey data were also analyzed to achieve the annual commercial air trips generated by and attracted to each West Virginia county.

The inadequacies of existing origin and destination commercial air travel data are discussed and recommendations are presented for improving the results of this type of survey.

Picado, Rosella, Air Trip Generation Model for Southern California, CE299 Report, Submitted for partial fulfillment for the requirements for the Master of Engineering degree, Department of Civil Engineering, University of California, Berkeley, March 1994.

Author Abstract: This report describes the process of estimating a trip generation model for air trips in Southern California. The objective of the work is to determine the pattern of air trip generation in order to later on evaluate the feasibility of different projects that have been proposed in this region, such as off-airport terminals or super-speed trains that will compete with the existing airports for traffic originating or terminating in the region.

The research has identified the following differences in trip generation patterns: residents against visitors, and type of origin for each of these groups; main purpose of the trip, grouped into business and non-business; and size of air party. The present model incorporates only the first set of factors, that is, type of air party and type of origin, for visitors only.

The models estimated are linear in the parameters, and use population, households, income and employment as explanatory variables. It was found that across the whole region the model underestimates trip generation by approximately 5%, although for individual zones the error in the estimation is much higher. A fundamental problem seemed to be that trip volumes vary by as much as three orders of magnitude across different zones, resulting in some zones carrying more weight in the final calibration than others.

A number of recommendations are made with respect to the estimation of trip generation rates from origin survey data. In particular, a series of problems found in the surveys hindered the development of a more disaggregate model. We hope that in the future this and other works done with this type of data will shed some light on the design and collection of trip origin information at airports.

Ruhl, Terry A., and Boris Trnavskis, "Airport Trip Generation," ITE Journal, Vol. 68, No. 5, May 1998.

This article reports on the result of a mail survey of 253 commercial service and general aviation airports in the United States to collect information on the number of vehicle trips generated by each airport in terms of the number of daily origin/destination passengers using the airport, the daily peaking characteristics, and the airport ground access mode split. The authors fitted a model to the data that expressed the average daily vehicle traffic as a function of the daily origin/destination passengers. The survey results showed that airport ground access mode splits varied widely by airport, even after controlling for airport size, although larger airports tended to have a higher percentage use of taxi, shuttle van, and public transportation.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

APPENDIX D

ANNOTATED BIBLIOGRAPHY

AIR SERVICE FORECASTING MODELS

Adler, Nicole, and Joseph Berechman, "Measuring Airport Quality from the Airlines' Viewpoint: An Application of Data Envelopment Analysis," Transport Policy*, Vol. 8, No. 3, July 2001.*

Author Abstract: The main objective of this paper is to develop a model to determine the relative efficiency and quality of airports. This factor seems to have a strong effect on the airlines' choice of hubs. Previous studies of airport quality have used subjective passenger data whereas in this study airport quality is defined from the airlines' viewpoint. Accordingly, we have solicited airlines' evaluations of a number of European and non-European airports by means of a detailed questionnaire. Statistical analysis of the median score has shown that these evaluations vary considerably relative to quality factors and airports. The key methodology used in this study to determine the relative quality level of the airports is Data Envelopment Analysis (DEA), which has been adapted through the use of principal component analysis. Of the set of West-European airports analyzed, Geneva, Milan and Munich received uniformly high relative efficiency scores. In contrast, Charles de Gaulle, Athens and Manchester consistently appear low in the rankings.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Fujii, Edwin T., Eric Im and James Mak, "Airport Expansion, Direct Flights, and Consumer Choice of Travel Destinations: The Case of Hawaii's Neighbor Islands," Journal of Travel Research, Vol. 30, No. 3, Winter 1992.

Author Abstract: This article reports a time series analysis of the impact of direct flights on tourism to Hawaii's Neighbor Islands beginning in 1983. Direct flights resulted in a modest gain in tourism and diverted travelers away from Oahu, and relieved congestion at Honolulu International Airport. To the extent that travelers were diverted from Oahu to the Neighbor Islands, income was redistributed as well.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

Hansen, Mark, "Positive Feedback Model of Multiple-Airport Systems," Journal of Transportation Engineering, Vol. 121, No. 6, November/December 1995

Author Abstract: A model for allocating passenger traffic in a multiple-airport system is proposed and tested. The model treats the supply side of the system as endogenous, and represents it implicitly using the principle that as air traffic using a airport increases, the airport becomes more attractive. This positive feedback effect and the preference of air travelers for airports near their trip terminus are argued to be the key factors determining the distribution of traffic in a multiple-airport system. The model is applied to the San Francisco Bay Area, served by airports in Oakland, San Francisco, and San Jose. A disaggregate logit airport-choice model, in which airport utility is a function of travel time to the trip origin, airport traffic in the origin-destination market, and airport enplanements, is estimated. The calibrated choice model, combined with estimates of the distribution of trip origins, is used to calculate equilibrium market shares. Comparison of equilibria with observed shares shows high correlation, particularly for larger markets, and for the San Francisco and Oakland airports.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Pels, Eric, Peter Nijkamp and Piet Rietveld, "Substitution and Complementarity in Aviation: Airports vs. Airlines," Transportation Research*, Part E, Vol. 33, No. 4, December 1997.*

Author Abstract: In this paper a model concerning substitution and complementarity on the linkage between airport facilities and airlines from the viewpoint of pricing policy is formulated. This model is used to analyze whether airport pricing policies, e.g. to ensure cost recovery, are compatible with competition for transfer passengers. It is found that airports with a high volume of demand can pursue cost recovery and still be the most preferred hub. Airports with a low level of demand will not be the preferred hub, even if the larger airport charges higher taxes to recover costs.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Pels, Eric, Peter Nijkamp and Piet Rietveld, "Airport and Airline Competition in a Multiple Airport Region: An Analysis Based on the Nested Logit Model," in Airport Facilities: Innovations for the Next Century, Proceedings of the 25th International Air Transportation Conference, Austin, Texas, American Society of Civil Engineers, Reston, Virginia, 1998.

Author Abstract: In a multiple airport region airlines compete with both other airlines operating from the same airport and airlines operating from alternative airports. In this paper symmetric equilibrium airfares and frequencies are derived for airlines operating from the same airports and for airlines operating from different airports. These equilibria are shown to be unique. Next, airport authorities are introduced as independent agents and equilibrium airport taxes, airfares and frequencies are derived and shown to be unique. Some simplifying assumptions are necessary to be able to derive these equilibria. We comment on the possibilities of relaxing these assumptions.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Proussaloglou, Kimon, and Frank S. Koppelman, "Air Carrier Demand: An Analysis of Market Share Determinants," Transportation*, Vol. 22, 1995.*

Author Abstract: Modeling air carrier demand is instrumental to understanding the relative importance of competitive forces that shape the airline environment and determine a carrier's market share. This paper develops a conceptual framework for analyzing carrier demand in a competitive context and applies that framework to study air carrier choice. This framework can be used by carriers to assess the market share and revenue implications of service design, pricing, marketing, and promotional strategies.

We adopt an individual traveler choice approach to identify and measure the relative importance of factors which influence air travel demand. Travelers' patterns of air travel, perceptions of carrier service, frequent-flyer program membership, and carrier choice behavior are used to estimate models of individual carrier choice. These models indicate the importance of carrier presence in the origin market, carrier service in a city-pair market (share of flights), carrier quality of service reflected in ratings by individual travelers, and traveler loyalty reflected in frequent-flyer program membership on carrier choice.

The importance of these variables and the specific quantitative relationship estimated can be used to estimate the market share impact of service design, pricing, marketing, and promotional changes. The empirical results of this study demonstrate the dramatic impact of frequent-flyer program participation on carrier choice for individual flights. These effects are particularly strong among the most important air carrier market, the frequent business traveler.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Proussaloglou, Kimon, and Frank S. Koppelman, "The Choice of Air Carrier, Flight, and Fare Class," Journal of Air Transport Management, Vol. 5, 1999.

Author Abstract: This paper reports the development and interpretation of air traveler choice models to gain insights into the tradeoffs air travelers make when they choose among different carriers, flights, and fare classes. Such insights can be used to support carrier decisions on flight scheduling, pricing, seat allocation, and ticket restrictions. This paper develops a conceptual framework and applies it to the choice of carrier, flight, and fare class as a basis for analyzing air travel demand in a competitive market. Model estimation results are used to quantify the importance of carrier preferences, market presence, quality of service, frequent flyer program membership, schedule convenience, and fares on carrier travel demand. The empirical results provide measures of the premium that business and leisure travelers are willing to pay to avoid schedule delays, to choose a carrier in which frequent-flyer program they participate, and to obtain the amenities and freedom from travel restrictions associated with higher fare classes.

Suzuki, Yoshinori, John E. Tyworth and Robert A. Novack, "Airline Market Share and Customer Service Quality: A Reference-Dependent Model," *Transportation Research, Vol. 35A, No. 9, November 2001.*

Author Abstract: Traditional models that explain the nature of the relationship between customer service quality and airline demand assume that the relationship can be approximated by using smooth or differentiable curves. Suzuki and Tyworth, however, recently argued that this assumption may not be valid, and that, if it is invalid, the model performance can be improved by using non-smooth functions to represent the relationship. We use their framework to develop a model that represents the relationship between service quality and market share in the airline industry and then empirically compare its performance with conventional airline demand models. The results indicate that the relationship is characterized by a non-smooth curve and that our model provides a significantly better goodness of fit than other conventional demand models.

Dr. Geoffrey D. Gosling
Aviation System Planning Consultant

CAMBRIDGE SYSTEMATICS INC.

SH&E

Wojan, Oliver W., "The Impact of Passengers' Preferences regarding Time and Service Quality on Airline Network Structure," *Journal of Transport Economics and Policy, Vol. 36, No. 1, January 2002.*

Author Abstract: The purpose of this paper is to explain the choice of network structure of a monopoly airline as well as flight frequency and aircraft capacity allocations across the network. The influence of travel time, flight frequencies, and service qualities are considered in relation to passenger behavior, and how they therefore affect network structure. The investigation shows that a profit-maximizing monopoly airline will adjust frequencies and capacities if traffic densities vary; while under symmetric demand airlines should either operate a hub-and-spoke or a point-to-point network.